FINAL REPORT

RESEARCH ON NAVY-RELATED COMBAT CASUALTY CARE ISSUES, NAVY OPERATIONAL-RELATED INJURIES AND ILLNESSES AND APPROACHES TO ENHANCE NAVY/MARINE CORPS PERSONNEL COMBAT PERFORMANCE

Prepared for

Naval Medical Research Institute
Bethesda, Maryland 20814

As Required By
Contract Number N00014-95-D-0048
(GC-2728)

Prepared by
GEO-CENTERS, INC.
7 Wells Avenue
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JULY 1998

GEO-CENTERS, INC.

GEO-CENTERS, INC.

July 6, 1998

Commanding Officer
Naval Medical Research Institute
8901 Wisconsin Avenue
Bethesda, MD 20814-5044

Attention: Lt. Richard A. Gustafson, Code 02/23

Reference: N00014-95-D-0048
GC-2728/3117

Dear Lt. Gustafson:

In accordance with the Contract Data Requirements List (DD Form 1423), ELIN A001, GEO-CENTERS, INC. is pleased to submit its quarterly progress report for the period March 1998 through May, 1998.

If you have any questions, please contact Dr. Monty Herron at (301) 231-6144 or the undersigned at (617) 964-7070.

Sincerely,

Monty Herron for

Robert P. Hallsworth
Contracts Administrator

Enclosure

cc: NRL/Code 2627 - 1 copy
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GEO-CENTERS, INC.

ANNUAL PROGRESS REPORT
OPTION YEAR TWO
GC-PR-2728-00

CONTRACT NUMBER: N00014-95-D-0048

REPORTING PERIOD: March 1, 1998 – May 31, 1998

REPORT DATE: July 6, 1998

RESEARCH ON NAVY-RELATED COMBAT CASUALTY CARE ISSUES, NAVY OPERATIONAL-RELATED INJURIES AND ILLNESSES AND APPROACHES TO ENHANCED NAVY/MARINE CORPS PERSONNEL COMBAT PERFORMANCE

I. INTRODUCTION

This report summarizes the results of GEO-CENTERS' technical activities for the second option year of the Naval Medical Research Institute (NMRI) Contract N00014-95-D-0048, Delivery Orders 002 and 004. The delivery orders encompass a variety of scientific studies that are capable of supporting ongoing and projected programs under the cognizance of NMRI; NMRI TOX/DET-Dayton, OH; NMRI/DET-San Antonio, TX; NDRI-Great Lakes, IL; the NDRI Detachment-Bethesda, MD; the National Naval Medical Center-Bethesda, MD; and the U.S. Navy Clothing and Textile Facility-Natick, MA.

The format for these periodic technical progress reports consists of four sections each listed by the location of the research. The sections are (1) Descriptions of work to be performed, (2) Objectives planned for the current reporting period, (3) Summary of work performed during current reporting period, and (4) Objectives for the next reporting period. As the final such report under this contract, objectives for the next period are not applicable. Accumulated scientific reports, technical reports and journal articles are being provided as part of this quarterly technical progress report. Specifically, the research conducted by GEO-CENTERS during this quarterly reporting period has been focused on the following general scientific programs:

A. Infectious disease threat assessment and preventive medicine programs.
B. Immune cell biology, wound repair and artificial blood studies.
C. Biomedical diving programs.
D. Breast Care Center.
E. Breast Cancer Research & Education Initiative (BRIN)
F. Directed Energy Effects Research
G. Dental related diseases.
H. Toxicological studies.
I. Human Performance and U.S. Navy Clothing Development

II. NMRI, Bethesda, MD

A. INFECTIOUS DISEASE THREAT ASSESSMENT AND PREVENTIVE MEDICINE PROGRAMS

CHRISTIAN, WOHLRABE

Description Of Work To Be Performed

- Provided assistance to the adenovirus surveillance project within the Preventive Medicine Division of Naval Hospital, Great Lakes, IL.
- Assist in the development and implementation of "Operation Stop Cough", a programmatic approach to reducing respiratory illness among Navy recruits.
- Assist with general infectious disease surveillance relevant to recruit respiratory illness.

Technical Objectives For The Reporting Period

- Continue culture surveillance for adenoviral illness among recruits.
- Continue to liaison between investigators, providers, laboratory staff, and patients to provide adenovirus surveillance information.
- Collect metrics on hygiene/handwashing for Operation Stop Cough
- Work with recruit training staff to assess options for improving access to hygiene and handwashing in boot camp.
- Assist with development of presentations for the Navy Occupational Health and Preventive Medicine Workshop and the TriService Recruit Healthcare Symposium.

Summary Of Work Performed During Current Reporting Period

- Assisted with report of a recent outbreak of adenoviral illness in recruits. Data prepared for Navy Environmental Health Center and Recruit Healthcare Symposium.
- Provided weekly assistance with streptococcal infection control, targeting prevention education to recruits and division commanders.
- Continued to distribute, collect, and arrange mail-out of culture materials for adenovirus surveillance. Provided acute quality control on culture media.
- Provided assistance to medical professionals in obtaining adenovirus cultures.
- Reviewed records and provided quality control for case reports of respiratory illness.
- Inspected handwashing facilities for recruits, as a quality metric for Operation Stop Cough.

JENDREK

Description Of Work To Be Performed

- Conducts fermentations in a BL-3 suite and depending on the organism of the fermentation may also perform some or all of the downstream processing associated with the project. Also creates all associated paperwork (standard operating procedures, batch records, etc.) with the fermenter and related equipment. Does much of the HPLC work towards optimizing current protein purification methods and procedures, as well as some of the Molecular Biology associated with this position.

Technical Objectives For The Reporting Period

- Will continue work on the LF production and write a batch record for the fermentation. Will then go back to the isoform separation work which was started just prior to the emphasis being placed on the LF project.

Summary Of Work Performed During Current Reporting Period

- The Lethal Factor producing strain of *B. anthracis* was completely optimized for the 20 liter level. It has been shown to be reproducible almost to the point at which overlay of the separate fermentations may be done. The harvesting of the fermentation needs to be worked out in order to increase protein recovery and decrease cell lysis. The batch record is currently about fifty percent complete, depending mostly upon which form of harvest is ultimately selected.

KERBY

Description Of Work To Be Performed

- Senior Scientist; Head of DSD Core Molecular Biology Support group, Diagnostic Systems Division, Systems Development Department: to develop diagnostic systems to detect and differentiate various viruses, bacteria, and toxins.

Technical Objective For The Reporting Period

- Design and synthesize primers and probes for DSD.
- Test various primers for their usefulness as PCR or sequencing primers.
- Continue with the automated sequence analysis of various viral and bacterial PCR products
- or clones.
- Continue the cloning of selected genes or fragments as needed.

Summary Of Work Performed During Current Reporting Period

- Synthesized sequencing and PCR primers for Anthrax, Plague, Q-fever, poxviruses, Ebola Hantaan, Dengue, and Shigella, as well as Biotin probes for these species.
- Tested eleven pairs of primers for orthopoxviruses, and three primer pairs for Anthrax and Brucella species.
- Verified the sequences of PCR products or clones of Poxviruses, Y.pestis, B.anthracis, F.tularensis, C.burnetti, S.aureus, and other agents.

MIHALIC

Description Of Work To Be Performed

- Provide technical laboratory assistance for the Diagnostic Systems Division at the United States Army Medical Research Institute of Infectious Diseases (USAMRIID) at Ft. Detrick, Md. The objective of the division is to develop and optimize assays for the detection of infectious diseases. My personal responsibilities at the time are in developing and optimizing electrophoretic assays applicable to the overall interests of the division.

Technical Objectives For The Reporting Period

Hantaan Western Blot Assay

- Establish quality control standards for assay.
- Validate assay with extended panel of human sera.
- Use knowledge of this assay to develop similar confirmatory assays for other viruses.
- Train someone else in the production of the western blot assay I developed so that we can make it a kit assay.

Recombinant Hantaan Project

- Assist in the production of a large quantity of recombinant hantaan nucleocapsid antigen for use in many assays.
- Help develop a fast, lateral flow assay to detect antibodies in sera. We will try and apply this assay to many different diseases such as hantaan and also plague.
- Begin working on the expression and purification of a recombinant Ebola protein.

Summary Of Work Performed During Current Reporting Period

Hantaan Western Blot Assay

- Presented a poster at The Meeting for The American Society of Tropical Medicine and Hygiene in Orlando, Florida.
- Established quality control standards for the Hantaan western blot assay.
- Began a time course study for the storage of western blot strips.
- Used similar format for a confirmatory Ebola western blot.

Recombinant Hantaan Project

- Sent a frozen stock away for upscaled production of recombinant Hantaan nucleocapsid.
- Developed growth and induction curves for the Ebola recombinant protein.

HEAVEY

Description Of Work To Be Performed

- Senior Scientist II conducting research on viral gene components involved in immunologic protection and detection.

Technical Objectives For The Reporting Period

Orthopoxvirus Project:

- Confirm sequences and transfer the cloned monkeypox virus genes into a VEE replicon for expression in vitro, and confirm expression of proteins in vitro.
- Initiate efforts to obtain variola genes though WHO, which may prove as useful targets for detection of orthopoxviruses in aerosols.

Filovirus Project:

- Evaluate post-challenge serum from guinea pigs which were immunized with VEE replicon expressing MBGV proteins via ELISA to determine if sterile immunity was obtained.
- Immunize a new group of guinea pigs with VEE replicons to examine the ability of individual gene products to protect against a heterologous challenge virus. Specifically, MBGV GP, NP, and VP35 will be used to immunize animals three times at 28 day intervals. After completion of immunization schedule, half the animals will be challenged with a homologous virus isolate and half with a heterologous virus isolate.

Summary Of Work Performed During Current Reporting Period

Orthopox Project:

- Several forms of poxvirus (vaccinia) antigen were produced. These include, cell associated vaccinia, vaccinia extracted with Genetron, and vaccinia extracted with Genetron followed by treatment with trypsin. This antigen was used in preliminary studies to determine if any of the production methods of antigen impact negatively on the ability of selected Mabs to recognize vaccinia virus in an ELISA.
- Cloned several genes from monkeypox virus that may be useful as targets for detection of orthopoxviruses in aerosols. Genes cloned from monkeypox (D8L, L1R, A33R, A34R, and H3L) were sequenced and then subcloned in the VEE replicon. The clones were examined for expression of protein and VEE replicon particle packaged.

- Arrangements were made for access to killed variola antigen at the Centers for Disease Control and Prevention in Atlanta, GA. This antigen will be used to confirm that Mabs which cross react with vaccinia and monkeypox in ELISA also react with variola.

Filovirus Project:

- Continued guinea pig challenge experiments to determine the efficacy of VEE replicon-based vaccines for Marburg virus (MBGV). Three lines of experimentation were begun or continued.
- Strain 13 guinea pigs were immunized with VEE replicons expressing either MBGV GP, GPTM, NP or VP35 3 times at 28 day intervals. For each antigen, animals were divided in half and one half challenged with a homologous virus (MBGV Musoke) and the other half challenged with a heterologous virus (MBGV Ravn), in order to evaluate the ability of replicon vaccination to induce a cross protective response. Experiment is ongoing with results expected in 1-2 weeks.
- Three different strains of guinea pigs were immunized with VEE replicons that expressed either MBGV GP, NP, or VP35. Three immunizations have been administered 28 days apart. Serum antibody titers have been determined, and animals will be challenged in the near future to determine if there is an effect of genetic background (i.e. MHC type) on protection with any of the antigens listed above.
- Strain 13 guinea pigs have been immunized with VEE replicons expressing MBGV GP, NP, or VP35. Three immunizations have been administered 28 days apart. Serum antibody titers will be determined. Serum and immune cells will be obtained from these immune animals for transfer into naive strain 13 guinea pigs to indicate whether antibody or cell mediated immunity is the predominant effector of protection.

II. NMRI, Bethesda, MD

B. IMMUNE CELL BIOLOGY, WOUND REPAIR RESEARCH AND ARTIFICIAL BLOOD PROGRAM

THOMAS

Description Of Work To Be Performed

Mr. Thomas, as Engineer III, serves as the Computer Aided Design Drafter(CADD) Manager, representing GEO-Centers, Inc., in support of biomedical research and development activities located at the Walter Reed Army Institute of Research(WRAIR)-Health Facility Planning Agency(HFPA) Office. He is responsible for organizing, managing and maintaining a CADD department and establishing a system of files and directories for working drawings. Mr. Thomas is also responsible for implementing procedures for manipulation of drawing files and developing user(working) drawings from existing documentation of new health facility.

Technical Objectives For The Reporting Period

- The primary objectives during this reporting period included developing user drawings of all floors of new health facility;
- Provide assistance to and coordinate with the Health Facility Planning Office(HFPO) and Corp. Of Engineers(COE) to facilitate updates and revisions to design of new facility;
- Provide technical training to COE, HFPO, Transition Action Team(TAT) and other staff members in utilizing CADD program-MicroStation Review;
- Other objectives include verifying hardware/software needs, determining items needed to further enhance the productivity of CADD department.

Summary Of Work Performed During Current Reporting Period

- Established a substantial quantity of user drawings;
- Generated drawings for HFPO and TAT staff, for use in presentations, meetings and tours of new facility;
- Trained various staff members in the use of CAD package;
- Determined needs and validated necessary purchases of plotter and printer equipment, paper and various other CAD and computer supplies;
- Attended MicroStation 95 conference/seminar to gain further knowledge, skills and tools available in MicroStation to assist in increasing productivity of drawing design.

II. NMRI, Bethesda, MD

C. BIOMEDICAL DIVING RESEARCH

OBOWA

Description Of Work To Be Performed

- Provide technical assistance in the Diving Medicine research laboratory investigating exposure to hyperbaric oxygen (HBO) and its effects on the CNS. Prepare brain and spinal cord tissues for histopathology, histochemistry and immunohistochemistry staining procedures. Responsible for small animal care and welfare. Perform surgical procedures on rats. Insure laboratory is maintained and adequately stocked.

Technical Objectives For The Reporting Period

- Development of a rodent model of spinal cord decompression sickness (DCS). This model will be utilized to evaluate pharmacological interventions for prevention and treatment of DCS in US Navy divers.
- Investigate what role vascular intracellular adhesion molecules may play in central nervous system ischemia/reperfusion injury.
- Study immuno-modulation in pathophysiology of DCS.
- Optimize immunohistochemical staining procedures to apply in DCS models.

Summary Of Work Performed During Current Reporting Period

- Prepared animal CNS tissues for all staining procedures.
- Assisted investigators with dive chamber operation.
- Responsibility for maintenance of laboratory facility and supplies.
- Completed the first phase for rodent DCS modeling. Tissue staining is still ongoing and we will transition some of this work to swine. More rodent DCS experiments are in planning stage.

PORTER

Description Of Work To Be Performed

- Support in the selection and testing of a hyperbaric CO2 analyzer for fleet submarine dry deck shelter use.
- Begin work on new tasking to develop and implement a field test plan for divers air bank sampling on 688 class submarines.
- Assist with other laboratory duties as needed.

Technical Objectives For The Reporting Period

- Continue the testing program for the hyperbaric CO2 analyzers approved for fleet use.
- Support new tasking to develop and implement a field test plan for divers air bank sampling on 688 class submarines.

Summary Of Work Performed During Current Reporting Period

- Six prototype hyperbaric analyzers completed a comprehensive testing program. Testing included months of hyperbaric testing in a laboratory hyperbaric chamber. Testing also involved collecting data from field sites aboard fleet dry deck shelters.
- A report based on the findings with the six prototype units was prepared and sent to NAVSEA.
- As a result of the favorable findings, thirteen new hyperbaric CO2 analyzers were ordered for fleet use. These analyzers where received and tested with a similar, but abbreviated, test plan.
- The new CO2 analyzers completed testing and were sent to US Navy Seal Delivery Vehicle Teams for fleet use.
- Ninety new sample bombs, and sampling equipment, were procured and assembled for 688 air bank test program. Actual testing to begin in FY98
- Air bank samples were collected on two 688 submarines due for DDS overhaul.
- Preformed other laboratory as requested.

Publications, Abstracts, etc.
Co-authored and constructed a poster presentation "Proposed Revised Procedures For Screening Diving Air For Dry Deck Shelter Operations" presented at the 1997 Undersea Hyperbaric Medical Society meeting in Cancun, Mexico (abstract attached).

II. NMRI, Bethesda, MD

E. BREAST CARE CENTER

GRIMES, JENKINS, MCGEE
Patient Service Representative

Description Of Work To Be Performed

- Process and interview patients, incorporate standard patient registration procedures. Maintain uniform policy for check-in/check-out procedures.
- Collect third party insurance forms on each patient.
- Receive patients and incoming telephone calls/inquiries, determine priorities and refer to proper person/department.
- Ensure that all incomplete patient records and third party forms are corrected or returned to proper staff for completion/correction.
- Set up records and filing system for paperwork associated with each patient record. Ensure that all documents processed are in accordance with department standards and that all forms are in designated order in the patient records. Label files for permanent shadow files.
- Orient new support team members and clinical team staff to office routine.
- Call all no-shows, record reason for not keeping appointment in shadow file and initial.
- Print Composite Health Care System (CHCS) daily schedule and end of day reports. Check end of day report for accuracy.
- ADS System: Educate providers, ensure completeness/accuracy of ADS forms, scan forms.
- Inform Technical Assistant of supply levels.
- Collect data for quality assessment project related to next available appointment for patients with new lumps.

Technical Objectives For This Reporting Period

- Change patient chart system.
- Modify division of duties based on personnel changes.
- Streamline and organize front-desk procedures.
- Retrieve and ensure completion of third party insurance forms
- Improve routing and response to incoming telephone calls/inquires
- Use standard registration procedures requiring plastic green card for imprinting all forms pertinent to each patient.
- Coordinate policies for scheduling appointments/procedures for patients calling/walk-ins/consults/cards.
- Streamline physician schedule notification process.
- Refine CHCS daily schedule and end of day reporting.

Summary Of Work Performed During Current Reporting Period

- Divided duties among remaining 2 Patient Service Representative Positions. Trained temporaries.
- Continued organization of front-desk procedures
- Processed and interviewed patients through CHCS and designated forms, obtained and updated all patient demographic information and ensured completion of forms.
- Obtained and verified pertinent insurance information utilizing available forms. Obtained third party insurance forms from physicians at end of each visit.
- Required identification card from each patient and imprinted all clinic forms pertinent to that patient.
- Received patients and incoming telephone calls/inquiries, determined priorities and referred to the proper source.
- Explained clinic procedures to patients.
- Obtain authorization for release of mammogram films from patient, for NNMC file tracking.
- Open monthly clinic schedules and make changes as necessary, based on physician schedule changes.
- Ensured completion of incomplete patient records and third party insurance forms.
- Set up records and maintain filing system for paperwork associated with each patient record. Ensured that all documents processed are in accordance with department standards. Filed all forms in designated order in patient record. Labeled files for permanent shadow files.
- Scheduled and coordinated front desk procedures in accordance with department policy. Identified process problems and helped develop suitable solutions.
- Oriented new support team members and clinical team staff to office routine.
- Participated in team planning to assure team members meet team quality standards. Maintain department standards of productivity.
- Notified physicians the day before they are scheduled for clinic; let them know approximately how many patients they will have.
- Continue working with the Ambulatory Data System (ADS):
- Prepare for Joint Committee for the Accreditation of Healthcare Organizations (JCAHO) inspection

KIDWELL

Description Of Work To Be Performed

- Manage and maintain the conference room schedules.
- Order supplies for various departments within the center.
- Manage and maintain the procurement process and database.
- Monitor data collected via CHCS and ADS for accuracy.
- Collect and report monthly man-hour reports.
- Manage patient and physician schedule templates in CHCS.

Technical Objectives for the Reporting Period

- Become proficient in Microsoft Access.
- Complete the patient chart filing system conversion if chart availability allows.
- Create an Internet page for the Breast Care Center.
- Update the Patient Service representative SOP.

Summary of Work Performed During Current Reporting Period

- Maintained conference room schedules in Schedule+.
- Maintained an adequate supply level.
- Attended a CPR training session course.
- Attended a Customer Service training session.
- Became proficient at Microsoft Access and maintained the procurement database.
- Participated in the coordination of the patient chart filing system conversion and played a major role in the conversion completed to date.
- Began creating a research database in conjunction with the Research Nurse.
- Continued working on the Breast Care Center Web page on the Internet.
- Continued capturing the data in Care Manager program of all certified letters sent to patients and consults returned to originators.
- Updated numerous Breast Care Center brochures and pamphlets.
- Attended equipment custodian training.

RICHMAN

Description Of Work To Be Performed

- Perform technical services including mammograms.
- Assisting in biopsies and ultrasounds.

Technical Objectives For This Reporting Period

- Perform various studies within the department thereby increasing knowledge and experience.
- Broaden understanding of the BCC's procedures and personnel. Expand relationship with BCC.
- Take full advantage of any educational opportunities which may arise as time and schedule permits.
- Continued to increase knowledge of mammography and breast diseases using the doctors as teachers.

Summary Of Work Performed During Current Reporting Period

- Performed a variety of mammograms, stereotactic biopsies, needle localizations and ultrasound procedures.
- Interfaced with mammography doctors to increase knowledge in the areas of mammography and breast disease.
- Worked on patient relations skills.
- Initiated a system to monitor screening program and call backs

HIGGINS

Description Of Work To Be Performed

- Continue to develop an education program for physicians and nurses on cancer genetics
- Continue to improve the screening process for patient participation in BCC research
- Continue to keep abreast on breast cancer issues using NCI Current Clips
- Continue to further develop personal computer skills
- Continue to attend seminars/conferences on breast cancer issues and professional nursing issues
- Contact tumor registry regarding patient identification for BRCA
- Continue BCC chart review to identify high risk and strong family history

- Organize and schedule BRCA Education Group
- Continue to recruit and register patients for participation in Tam/4-HPR
- Continue to prepare selected pedigrees and reports for weekly pedigree meetings
- Conduct individual and group presentations for BRCA education/counseling
- Continue to act as liaison between BCC and other governmental/research institutions
- Continue to prepare data packets for NCI research nurses working with Tam/4HPR
- Utilizing Care Manager to identify trends of care in the BCC and to document nursing notes
- Keeping the BCC staff abreast of research issues relevant to patient care and staff development
- Continue to attend Graduate School to further enhance nursing knowledge
- Participation and case study presentation at BCC staff meetings and multidisciplinary meetings
- Update and maintain protocol log books
- Attend tumor board weekly
- Prepare and distribute minutes of weekly research meetings in the BCC

Technical Objectives For This Reporting Period

- Research overview of BCC ongoing protocols to distribute to outside providers
- Utilizing Care Manager to identify trends of care in the BCC and to document nursing notes
- Advertisement for patient education program, i.e. flyers and memos
- Evaluation forms for general education group
- Prepare handouts of questions and answers about genetic testing to distribute at general education meetings
- Log book for Oncor Med specimen issues
- Excel data for Tam/4HPR study
- Work collaboratively to design data base for BRCA study
- Organize and distribute minutes for BCC research meetings
- Improved chart review process
- Completed task synopsis of research nurse position for review by administration

Summary Of Work Performed During Current Reporting Period

- Prepared and distributed minutes of weekly research meetings in the BCC
- Prepare selected pedigrees and reports for weekly pedigree meetings
- Attended breast cancer symposium at Portsmouth as a guest speaker
- Collaborated with NSABP research nurse on menstrual cycle protocol
- Prepared and forwarded date information packets for Tam/4HPR patients to the NCI
- Completed patient information booklet to provide information post education session
- Data collection forms and log-books of patients on protocol

- Conducted the general education group for patients, "Genes and breast Cancer"
- Became more active in the cultural awareness committees
- Revised Tam/4-HPR pathway
- Developed method for follow-up post results
- Registered additional patients on TAM/4-HPR and BRCA protocol
- BCC chart review to identify high risk and strong family history
- Created ovarian screening consults for referrals
- Attended tumor board weekly
- Organized and scheduled the BRCA Education Group
- Conducted individualized and group patient information sessions for BRCA
- Kept the BCC staff abreast of research issues relevant to patient care and staff development
- Reviewed and documented on genetic material received from the National Action Plan on Breast Cancer
- Attended Graduate School to further enhance nursing knowledge
- Updated and maintained protocol log books

LOUIE

Description Of Work To Be Performed

- Serve as mammographer in the department of radiology at National Naval Medical Center (NNMC).
- Serve as consult for referral cases from outside institutions as well as the Breast Care Center (BCC) here at NNMC. Many of these are complex cases which are sent to NNMC for further evaluation or a second opinion.
- Serve as liaison between the medical staff in the BCC and the mammography section of the radiology department.
- Serve as consultant radiologist for weekly surgical tumor board meetings.
- Supervise the radiology resident assigned to the mammography section of the radiology department.
- Serve as consultant to radiology staff regularly rotating through the mammography section.
- Supervise the mammography technologists to insure that the mammograms meet American College of Radiology (ACR) and Food and Drug Administration, Division of Mammmography (FDA) standards for mammography accreditation.
- Investigate, initiate and participate in the planning of other mammography research projects in which NNMC may be a participant.

Technical Objectives For The Reporting Period

- Continue to follow and further develop the protocols established in the mammography section for evaluating patients with breast abnormalities.
- Continue to perform stereotactic needle core breast biopsies.
- Continue to perform and increase the number of ultrasound guided procedures of the breast, as well as ultrasound scans of the breasts for focal abnormalities.
- Continue to supervise and teach the radiology residents rotating through the mammography section.
- Begin to replace the 14G Biopty gun with the 11G Mammotome device for stereotactic biopsies.
- Determine guidelines for which patients are the optimal candidates for the Mammotome biopsy device.

Summary of Work Performed During Current Reporting Period

- Continue to serve as one of the two principal mammographers in the department. I am more frequently on the schedule and read more mammographic studies than any other radiologist assigned to the section. There are up to 4 half days each week when I am the only mammographer working in the department.
- Continued to perform stereotactic needle core biopsies of the breast as well as needle localizations for surgical excisions, on a regular basis.
- Awaiting the final approval of minor revisions to the proposal to demonstrate the feasibility of imaging the breast with fluorodeoxyglucose (FDG) using a gamma camera. This procedure has never been published before, and will involve a collaboration of the nuclear medicine and mammography departments of NNMC. (Note that only a minority of proposals are approved the first time they are submitted.)
- Increased involvement in teaching the radiology residents as they rotate through the mammography section.
- Continue to identify interesting cases to add to the resident teaching file.
- Continue to serve as liaison between BCC and the mammography department. The latter is often not informed on decisions and projects taking place in BCC.
- Continue to identify very high risk patients who may be interested in the BRCA gene education and screening program now offered by BCC. These names are forwarded to Sherry Higgins in BCC for future contact.
- Participate in the regularly scheduled BCC research meetings to address ongoing and potential projects involving BCC, how to facilitate the creation of new projects, and how to improve interdepartmental and interinstitutional communication for new projects.

- Continue to attend the Breast Cancer Think Tank workshops sponsored by the NCI to foster collaboration between clinicians and laboratory researchers in their quest for new treatments and cures for breast cancer.
- Begin to refer patients with complex problems to MRI for breast MR and to nuclear medicine for scintimammography. (The latter is separate and different from the above described FDG protocol.) Imaging of the breast now often requires multiple modalities, and this idea was reinforced at the recent Chicago meeting of the Radiological Society of North America (RSNA).
- Finished participation as a reader for a digital and computer-assisted diagnosis mammography project run by Uniformed Sciences University of the Health Sciences (USUHS) and the University of South Florida.
- Successfully instituted screening mammography program, approximately doubling the patient volume with little disturbance of the present patient schedule.
- Lecture to nurses attending the Educate the Educator course hosted by BCC. (I also spoke at the previous course in Aug 97.)

O'HALLORAN

Description Of Work To Be Performed

- Support a research program which focuses on breast cancer.
- Liaison between the Radiology Department-Mammography Section, the Breast Care Center (BCC), and other hospital departments.
- Perform nursing duties.
- Perform managerial duties.

Technical Objectives For This Reporting Period

- Assist the Radiologists/staff with stereotactic and ultrasound guided breast biopsy procedures.
- Perform assessments on all stereotactic/ultrasound biopsy patients and provide these patients with post breast biopsy teaching instructions.
- Assist with continued development between the BCC and Radiology Department.

Summary of Work Performed During Current Reporting Period

- The above technical objectives were met during the current reporting period.
- Completed familiarization with the role of Radiology Nurse Case Manager
- Assisted with the training of new ambulatory care nurses in the Breast Care Center
- Re-organized the mammography scheduling process.
- Supervised other mammography personnel.
- Acted as clinic manager for the Mammography Division.
- Tracked 6 month follow-up patients with outcome analysis via BCC Task Management Tool.
- Correlated mammography and pathology findings via CHCS.

ROGERS

Description Of Work To Be Performed

- The social worker will interview and assess newly diagnosed breast cancer patients and provide them with educational materials, support group information, and a description of available social work services. The assessment will include a screening for depression and adjustment, the documentation of the patient's social history and a defining of the patient's environmental support systems.
- The social worker will evaluate and monitor the breast cancer patient's psychosocial and mental status and offer individual, couple, family, or group psychotherapeutic intervention or referral as appropriate.
- The worker will encourage and facilitate the identification of the patient's concrete needs and concerns and actively participate with the patient in a solution and task focused pursuit of such.
- Facilitation of the Stage I & Stage II Breast Cancer Survivor Group
- Facilitation of the Advanced Breast Cancer Support Group
- Facilitation of the Male Partners and Caregivers of Breast Cancer Patients Support Group
- Solicit new member participation in the aforementioned Breast Care Center support groups.
- Collect and analyze the support group research data related to the Adjustment and Social Support in male partners and caregivers of Breast Cancer Patients.
- Act as the liaison between the Breast Care Center and the National Naval Medical Center Social Work Department. As such, the worker will attend social work staff meetings, offer professional coverage and other services when necessary, coordinate communication, and maintain colleague rapport and interaction.
- Coordinate Breast Care Center patient participation in the American Cancer Society "Look Good, Feel Better" program for patients undergoing or having completed radiation and chemotherapy treatments.

Technical Objectives For The Reporting Period

- Address the psychosocial and concrete needs of individual patients in the Breast Care Center.
- Provide individual psychotherapy to patients experiencing significant emotional distress following diagnosis.
- Facilitate on-going therapy for patients who have experienced specific types of concerns at the completion of treatment including sexuality and intimacy issues, fear of recurrence, family concerns, etc.
- Facilitate psychotherapeutic intervention with couples who wish to enhance coping skills and increase the level of communication, sense of well-being, and stability in their union during a time of dramatic change and crisis following the diagnosis of breast cancer.
- Develop social work involvement with the BRCA Gene Study. Social Worker will serve as individual providing therapy to patients who experience anxiety, depression or other feelings related to the gene testing process and results of the tests. Examining the option of starting a genetic support group.
- Provide instructional lecture regarding social work intervention to participants of the Nurse Case Management Curriculum.

Summary of Work Performed During Current Reporting Period

- Addressed the psychosocial status and patient/family concerns in the Breast Care Center.
- Worked closely with the Breast Care Center Nurse Case Managers to provide seamless care to patients. This included daily integration and discussion of services provided to ensure a continuity patient care and enhanced patient satisfaction.
- Provided facilitation of the Advanced Breast Cancer Support Group, the Stage I & Stage II Breast Cancer Survivor Group, and the Male Partners and Caregivers of Breast Cancer Patients Support Group.
- Worked closely with the CHAMPUS and Supplemental Care offices to ensure that patients wig and breast prosthetics requirements were approved prior to the purchase of such items.
- Actively promoted the Breast Care Center Breast Cancer Survivor groups resulting in increased new membership.
- Provided coverage of emergent psychosocial issues, attended multidisciplinary hospital discharge meeting, and supervised intern team during the social work department mandatory retreat.
- Attended National Naval Medical Center Social Work Department meetings, offered ongoing professional coverage, coordinated communication, and maintained constant collegial interaction.
- Completed all required training, seminars, and paperwork in anticipation of an inspection by the Joint Commission for the Accreditation of Healthcare Organizations.

- Attended and actively participated in meetings of the Medical Ethics Committee of the National Naval Medical Center.
- Attended and actively participated in weekly multidisciplinary rounds on oncology unit of the National Naval Medical Center.
- Coordinated Breast Care Center patient participation in the American Cancer Society "Look Good, Feel Better" program.
- Updated and improved a comprehensive listing of wig salons for patients who are undergoing chemotherapy and may need to locate a wig prosthetic as a result of hair loss.
- Amended and enhanced a comprehensive listing of local lodging with current prices and military or patient discount information for use by patients and their companions.
- Provided informational lecture on social work intervention for participants of Nurse Case Management Curriculum.
- Completed required Provider Education Seminar on Tricare - Sierra Military Health Services coverage, care options, and mental health services which will soon be implemented.
- Fulfilled requirements toward clinical licensure by maintaining a schedule of weekly meetings with professional mentor and supervisor.

SNEE, LAHL

Description Of Work To Be Performed

- Perform case management for new breast cancer patients
- Utilizes the "Care Manager" and "Care Charter" software to document and track the patient's progress through the clinical care pathway of breast cancer treatment
- Helps to educate newly diagnosed breast cancer patients about disease, treatments, and follow up care
- Provides educational materials to patients and families
- Coordinates and plans appointments for multidisciplinary care in hospital, including, but not limited to hematology/oncology, radiation/oncology, plastic surgery, physical therapy, and social services
- Provides emotional support to women and their families who are facing cancer treatment through verbal and nonverbal communication
- Provides support, comfort, and education to the patient through the use of pre and post op phone calls and by visiting the patient while they are an inpatient.
- Ensures that patients are receiving adequate follow up care
- Tracks breast biopsies and notifies doctor of any malignant pathology reports and ensures that patient is scheduled for appointment with physician
- Teaches and demonstrates the "Care Manager" and "Care Charter" software to interested personnel both within NNMC and at outside facilities
- Assists as needed in clinic as either ambulatory care nurse or nurse educator

Objectives For The Current Reporting Period

- Assists in the orientation and training of new personnel in the BCC
- Continues to provide "Care Manager" and "Care Charter" demonstrations to interested parties coming to the BCC
- Ongoing development in the role of the nurse case manager
- Implement processes that will enable appropriate follow up care for breast cancer patients
- Continues to revise and perfect methods to discuss cancer diagnosis with patients
- Continues to gain further knowledge and education in breast cancer and its treatment
- Ongoing development of organizational skills to manage multiple patients and their individual need

Summary of Work Performed During Current Reporting Period

- Provided documentation of breast CA staging, including complete pathology reports to BCC shadow record and to tumor registry for patients diagnosed with breast cancer since 1/1/98
- Assisted in the presentation and development of the "Nurse Case Management Curriculum" that was provided to ten visiting nurses from around the country in 4/98
- Assisted in the training of new ambulatory care nurses
- Provided education and working demonstration of the "Care Manager" software to interested personnel both within NNMC and to outside facilities
- Collaborated with the computer software company "Ellora" to provide information related to case management and breast cancer for the development of the new software "Care Central"
- Functioned as an ambulatory care nurse/triage nurse during periods of low staffing and/or high patient volume
- Helped to educate patients and families on breast cancer
- Provided emotional support to women from diagnosis to completion of of breast cancer treatment
- Collaborated with multiple disciplines to arrange for patient care
- Developed useful methods for managing many varied and complex patients
- Attended tumor board meetings and was prepared to give additional information concerning breast cancer patients if required or requested by physicians
- Collaborated with staff on the development of a cancer database
- Collaborated with the nursing staff to begin the redesign of the ambulatory nursing role

SNYDER

Description Of Work To Be Performed

- Develop and integrate a breast care educational program for female/male Department of Defense beneficiaries and their support persons.
- Educational program to include all breast care issues with an emphasis on early detection of breast cancer.
- Provide pre-operative teaching and educate patients regarding breast cancer and treatment options.
- Being available as an information resource person for the patient and their support person.
- Plan staff development programs and maintain BCC staff development records.
- Act as relief Ambulatory Care Nurse under the direction of the nurse manager.
- BCC designated safety representative, responsible for safety manuals, monthly safety meetings and BCC safety issues.
- BCC representative on the Education Council Committee.
- BCC representative on the Nurse Practice Committee.

Technical Objectives For This Reporting Period

- Continue to provide patient education.
- Continue to develop array of patient educational materials.
- Continue to act as relief ambulatory care/ triage nurse.
- Continue staff development and safety representative responsibilities.

Summary of Work Performed During Current Reporting Period

- Continued responsibility as the designated safety representative of the BCC.
- Participated in command sponsored health fairs.
- Maintained credentialing database on all Geo-Center employees.
- Plans and institutes staff education calendar and events.
- Functions as Clinical Educator providing teaching on breast self-examination, pre and post-operative instruction and breast cancer.
- Functioned as relief ambulatory care/ triage nurse providing breast self exam teaching, assisting the physicians with physical exams, procedures, and scheduling of diagnostic tests when needed.
- Continued to review educational materials and order needed materials.
- Preparation/ Implementation of the Orientation program for the new employee RN.
- Participation on the Educational Council Committee.
- Participation on the Nurse Practice Committee.

- Provided the Breast Cancer lecture for the Oncology Course.
- Assist with the management of the Nurse Case Manager Curriculum.
- Preparation of staff training files and staff education for the arrival of JCAHO.

VAUGHN

Description Of Work To Be Performed

- Process and interview patients in need of mammogram
- Maintain uniform policy for scheduling mammography procedures
- Print and update daily mammography schedule
- Print pending orders list each day, contact and schedule appointments for patients in need of mammogram
- Receive patients and incoming telephone calls/inquires, determine priorities and refer to proper person/department
- Enter CHCS orders for comparison mammograms
- Ensure that all incomplete or incorrect patient mammogram orders are corrected or returned to proper staff for completion/correction
- Handle mail and telephone correspondence regarding mammography scheduling
- Call all no-shows and attempt to re-schedule mammography appointments
- Set up records and filing system for paperwork associated with each patient record. Ensure that all documents processed are in accordance with department standards and that all forms are in designated order

Technical Objectives For This Reporting Period

- Improve routing and response to incoming telephone calls/inquires
- Coordinate policies for scheduling mammography appointments for patients calling, walk-ins, and consults
- Refine CHCS daily schedule
- Modify duties based on personnel changes
- Improve mammography scheduling to allow for more efficient operations
- Be readily available for assistance to co-workers, the mammography department, physicians, and patients requiring assistance with mammography

Summary of Work Performed During Current Reporting Period

- Received patients and incoming telephone calls, determined priorities
- Provided assistance to staff requesting help with mammography orders
- Continued to organize log book to improve mammography scheduling

- Performed increased duties as patient volume increased within the BCC and Radiology Department
- Explained mammography procedures to patients
- Obtained authorization for release of mammogram films from patients, for NNMC file tracking
- Open mammography schedules and make changes as necessary, based on departmental needs
- Worked closely with BCC staff to ensure timeliness and accuracy of diagnostic mammography slots
- Oriented new staff to file room procedures and duties
- Participated in team planning to improve mammography scheduling
- Promoted to the mammography scheduler in 10/97. Transitioned to this new position

WALLACE

Description Of Work To Be Performed

- Act as Administrator of the Breast Care Center, responding to the needs of patients and staff to meet daily administrative requirements
- Oversee/Manage appointment scheduling system that allows for: maximum access of patients into the clinic, provides for medical training, research protocols, and administrative time, and is responsive to unanticipated demands and special cases.
- Gather workload data, prepare statistical reports, and analyze data to provide information and guidance.
- Patient ombudsman for the Center during Nurse Manager's absence.
- Coordinate input in order to prepare the annual budget, mid-year reviews, and unprogrammed requirements for the Center. Provide recommendations to the administrative team in the development and formulation of budget requests, based on familiarity and knowledge of Department programs and appropriate procedures, review and analyze budget requests, and determine whether requests for funds and expenditures are proper, necessary, and timely. Monitor use and rate of expenditures of budgeted funds. Oversee funding for all research conducted at the Center, with particular emphasis on clinical trials.
- Responsible for coordinating responses to all correspondence that comes into the Center. This includes Congressional inquiries, complaints, requests for information, requests for guest speakers, etc.
- Coordinate all reports generated in the Center. This includes establishment of a system that will guarantee reports are on time and that all reports reflect accurate data.
- Maintain oversight of equipment inventory and ensure that equipment is maintained.
- Review space utilization within the Center and advise the administrative team on such activities as space allocation and renovation.

- Supervise GEO-CENTERS, INC personnel located in the Breast Care Center, Building 10, 4th Floor, West..
- Manage information systems hardware and software within the Center. Maintain oversight of CHCS and ADS use within the Center.
- Maintain oversight of the ordering process for supplies.
- Primary liaison between the military and GEO-CENTERS, INC.
- Provide advice on manpower utilization, work flow, and operational procedures.
- Respond to requests for administrative reports; generate, collate, synthesize and present a wide range of data in written or oral form; edit reports prepared by other members of the Department; and, confer with the administrative team in identifying and resolving administrative problems and needs.
- Coordinate staffing with the Nurse Manager, analyze manpower utilization and participate in interviews.
- Monitor legal issues. Make Staff Judge Advocate's office aware of potential litigation.
- Work with administrative team to develop plans for guiding future clinic operations.
- Assist Contract Management Department with maintaining accurate and complete files on contract employees.
- Assist in preparation for VIP tours and briefings.
- Other administrative functions as necessary.

Technical Objectives For This Reporting Period

- Oversee conversion of patient charting system. Ensure completion of conversion next Quarter.
- Analyze current staffing and future staffing needs. Determine effectiveness of current nursing staff positions. Hire personnel as necessary. Orient new employees.
- Monitor Breast Cancer Prevention, Education, Diagnosis Initiative issues closely. This includes preparation of Statements of Work and proposals for obligation of future funding and completion/ submission of expenditure of funds reports to the Office of the Assistant Secretary of Defense and Tricare Region 1 Lead Agent's office.
- Monitor system for checking data accuracy, with particular attention to use of CHCS, ADS and CareCentral Software.
- Ensure compliance with the Surgeon General's ADS standards.
- Attend weekly meetings of the Information Management Quality Management Board to keep up-to-date on all information systems issues.
- Oversee procurement ordering process. Make sure all necessary supplies are ordered in a timely fashion. Ensure proper documentation.
- Participate in genetics research and cancer database development working groups.
- Act as Point of Contact and Coordinator of the John Silva/Defense Advanced Research Projects Agency project to develop an electronic patient file.
- Assess Ellora Software Inc. projects status. Monitor fund use versus project completion.

- Prepare for Joint Commission for the Accreditation of Healthcare Organizations (JCAHO) inspection.
- Prepare organization for TRICARE.
- Prepare for Nurse Manager's absence on ship (2 months).
- Takeover process improvement to streamline ambulatory care floor operations.
- Takeover project to "fix" the multidisciplinary care clinic.

Summary Of Work Performed During Current Reporting Period

- Prepared for JACHO inspection.
- Monitored legal issues.
- Monitored compliance between BCC records and Budget Department records. Completed retrospective budget review and projected funding status for the next two fiscal years.
- Investigated and implemented methods to improve current work practices.
- Coordinated administrative activities of the BCC.
- Continued oversight of chart conversion.
- Analyzed staffing needs to determine effectiveness of current staff positions. Handled personnel matters.
- Oversight of schedule templates, with emphasis on current and future changes related to TRICARE as well as changes related to our transition to a new computer system.
- Maintained relationship with Contract Management Department.
- Handled daily administrative issues as necessary.
- Monitored Breast Cancer Prevention, Education, Diagnosis Initiative issues closely. This included preparation of first quarter reports, receipt of funds and establishing mechanisms for funds expenditure.
- Attended weekly meetings of the Information Management Quality Management Board.
- Oversaw procurement ordering process. Made sure all necessary supplies were ordered in a timely fashion.
- Participated in genetics research and cancer database development working groups.
- Acted as Point of Contact and Coordinator of the John Silva/Defense Advanced Research Projects Agency project to develop an electronic patient file.
- Hosted multiple distinguished visitors

MANUEL-SIMPSON

Description Of Work To Be Performed

- Coordinate patient flow activities
- Perform vital signs check and determine reason for patient visit.
- Prepare patient charts with appropriate medical, lab ,and x-ray reports
- Assist physicians with all procedures such as FNA or cyst aspirations
- Provide physical and emotional support to patients during their appointment
- Collaborate with a multidisciplinary staff concerning patient needs and identify patients who may benefit from services such as social service, physical therapy, or nurse case management
- Responsible for preparing all clinical areas for patients and securing clinical areas at the end of the day
- Process linen and hazardous wastes within the BCC
- Maintain supplies at par level and records supplies needed
- Coordinate with Ambulatory Care Registered Nurse. Inform Ambulatory Care Nurse of arrival and departure from the floor. Inform Registered Nurse of additional patient needs
- Data collection for various purposes, including patient risk factors, patient vital signs, and other projects as necessary
- Cross train with Patient Service Representatives

Technical Objectives For This Reporting Period

- Become oriented to the Breast Care Center, complete training and competency requirements.
- Develop in the role of Medical Assistant.
- Receive training and develop computer skills, especially the use of hospital system called CHCS
- Gain knowledge and education in breast cancer and its treatment
- Continue to learn Breast Care Center operations.

Summary of Work Performed During The Current Period

- Coordinated patient flow activities
- Performed vital signs check and determine reason for patient visits
- Prepared patient charts appropriately with medical, lab, and X-ray reports
- Assisted physicians with procedures done in the BCC
- Provided physical and emotional support to patients
- Collaborated with social service, nurse case manager, clinical nurse educator, physical therapist and many physicians to ensure exceptional patient care
- Disposed of linens and hazardous wastes appropriately

FERGUSON

Description Of Work To Be Performed

- Medical filing for the Radiology department and the Breast Care Center.
- Enter CHCS orders for comparison mammograms.
- Track mammogram films.
- Handle mail and telephone correspondence regarding radiology films.
- Pull and file mammograms.
- Make copies of mammogram films for physicians.

Technical Objectives For This Reporting Period

- Alphabetize the main mammography file system.
- Systematic checking for quality improvement.
- Improve report filing to allow for more efficient operations.
- Being readily available for assistance to co-workers, the BCC staff, physicians and patients requiring assistance with mammography films.

Summary of Work Performed During Current Reporting Period

- Provided assistance to staff requesting help with mammography films.
- Continued to organize log book to improve film tracking.
- Continued to disseminate films to patients via CHCS computer.
- Assisted radiologists with research projects by providing mammogram films.
- Performed increased duties as patient volume increased within the BCC.
- Was promoted to the mammography scheduler in 10/97. Started to transition to this new position and continued with file clerk duties as described above.

Goals/Objectives for the Next Reporting Period

- As I have transitioned to the permanent position of file clerk, will become more proficient with the mammography filing process.

WISE, GIBEAU, GALLIGAN

Description Of Work To Be Performed

- Collaborates with a multidisciplinary staff concerning patient needs and identifies patients who may benefit from services such as social service, physical therapy or nurse case management.
- Performs professional nursing assessments
- Opening and closing all clinical areas and preparing exam rooms for patient use
- Triage of telephone calls and patient walk-ins
- Responsible for daily clinic functions
- Enters physicians orders as needed
- Reviews and sorts pathology and mammogram reports
- Oversees preparation of charts for patient visits
- Assignment of nursing lunch breaks to ensure appropriate coverage of the unit
- Processes linen and hazardous material
- Maintains supplies for clinical exam rooms and needle/syringe cart
- Coordinates all FNAs and procedures and notifies Nurse Case Manager of positive diagnosis
- Performs biopsy teaching and APU coverage in absence of Clinical Nurse Educator

Technical Objectives For This Reporting Period

- Become familiar with position
- Organization of patient charts
- Maintain mammography-scheduling book
- Modification of daily clinic schedules
- Utilization of Care Central for tracking of FNAs
- Continue to improve computer skills
- Identify nursing roles for ambulatory care setting
- Stocking of all clinical areas
- Breast self-examination teaching
- Organization of triage area and triage files
- Participating with multidisciplinary team in obtaining a Web site for the Breast Care Center
- Providing physical and emotional support to patients

Summary Of Work Performed During Current Reporting Period

- Participated in multidisciplinary meetings to further enhance the relationship between BCC, SSU and GSC
- Enhance nursing knowledge base on breast cancer issues
- Further developed personal computer skills
- Triage telephone calls and walk-ins
- Further identified the nursing assignments of the ambulatory care staff
- Coordinated all FNAs and procedures and notify Nurse Case Manager if positive
- Oriented new staff member to patient flow processes and forms within the BCC
- Coordinated patient flow activities in the clinical areas with patients, nurses and physicians

II. NMRI, Bethesda, MD

F. BREAST CANCER RESEARCH & EDUCATION INITIATIVE (BRIN)

BELLITT, ELLIOTT, FREEMAN, FUSCHINO, HAMMA, MATTHEWS, SEMONES, STEWART, WHITEHEAD

Description Of Work To Be Performed

- The Department of Defense (DoD) has recognized and emphasized the importance of increased awareness and education regarding breast cancer and screenings. There are about two million DoD women beneficiaries over the age of 30, which represents 26% of all Military Health Services System (MHSS) beneficiaries. Thirteen percent of the active forces are women, and each year nearly 18,000 new cases of breast cancer are diagnosed in the MHSS. It is through education and awareness of the importance of clinical examinations, mammography, and monthly breast self-examinations (BSE) that breast cancer mortality can be decreased while positively affecting the morale of the DoD workforce.
- The FY97 BRIN Program utilizes a three-phased approach. Phase I focuses on beneficiary access to breast cancer screening, diagnosis, and treatment. Phase II will be implemented by the Military Treatment Facilities (MTFs), and focuses on training programs for all MTF Primary Care Managers on clinical breast cancer examinations and BSE techniques for beneficiaries. Phase III focuses on region-wide education programs.

Technical Objectives For The Reporting Period

- Enrolling patients in breast Care Programs.
- Developing pre and post care guidelines for stereotactic and ultrasound guided core biopsies.
- Increasing access by decreasing time between diagnosis of potential problem to mammogram or ultrasound guided core biopsy.
- Provide breast care education programs to the MTF community.
- Develop a Mail Education Reminder Program.

Summary Of Work Performed During Current Reporting Period

- Continue to provide high quality images for accurate radiologic interpretation.
- Maintained film processors within the set guidelines reducing departmental down time.
- Continue to mentor newer technologists by setting realistic goals and providing guidance.
- Decrease time to mammogram or ultrasound guided core biopsies from 5 months to in some cases, less than 24 hours.
- Set up a schedule and implemented the first wave of the Mail Education Reminder Program
- Held various breast care training sessions throughout the region.

II. NMRI, Bethesda, MD

G. DIRECTED ENERGY EFFECTS RESEARCH

ELLIOTT

Description Of Work To Be Performed

- Continue a training program for Rhesus monkeys with ultimate goal of animals trained to perform visual acuity tasks while aligned on and being imaged by, a Scanning Laser Ophthalmascope.
- Continue experiments in optical physics and ocular physiology
- Operate, and maintain Rodenstock Scanning Laser Ophthalmoscope(SLO).

Technical Objectives For The Reporting Period

Define Animal Performance criteria:

- The objective of this research is to simultaneously evaluate the effects of Q-switched laser exposure on the behavioral indices of visual performance and retinal morphology of Rhesus monkeys performing visual tasks while retinal imaging with SLO takes place. This training program involves a sequence of interim training objectives: Reaction Time Observing Response, Stimulus refinement, Modification of apparatus, Mask training, SLO conditioning and training.
- Continue optics and ocular imaging research program: Small eye experiments, SLO image enhancement, Laser/Retinal lesion mechanism/treatment pilot program.

Summary Of Work Performed During Current Reporting Period

Training Program

Animal training progress is nominal. The apparatus has been modified and subjects familiarized. Masks have been designed, fabricated and installed.

SLO Operation

The new Rodenstock SLO is in routine operation.

Optics and Ocular physiology

Small eye subjects have been selected and maintained. Laser injury treatment substances identified, selected and acquired.

GUILLORY

Description Of Work To Be Performed

- Compile and analyze data comparison of tactical in-flight information versus visual data collected via manual video tracking (spatial analysis).
- Assist in logistical support as necessary.

Technical Objectives For This Reporting Period

- Reinforce information to pilots of the threat that handheld lasers pose to any flight operation.

Summary of Work Performed During Current Reporting Period

- Acquired spatial positioning data from actual flight sensor data comparison (data scoring).
- Provided daily research and administrative support.

RICHARDSON

Description Of Work To Be Performed

- Provide Biological Science Laboratory Technician (Animal) Support to the Microwave Department. Handling and training of non-human primates. Recording and compiling data. In-house management of non-human primates. Administrative support of animal use projects.

Technical Objectives For The Reporting Period

- Provide technical support to other personnel with their projects, and assist where needed in animal research.
- Recording data and compiling data on computer programs for publishing.

**Summary Of Work Performed During
Current Reporting Period**

- Assigned duties as Lead Technician in the Millimeter Wave Eye Project.
- Attended and completed computer courses in order to better perform data collection and analysis duties.
- Responsible for animal vivarium, ensuring compliance with AALAC standards, animal health and welfare and functioning as the Detachment Liason with Vet Sciences.

THOMPSON

Description Of Work To Be Performed

- Provide technical and analytical support for pulsed laser glare projects.
- Provide support in the experimental design and analytical support for visual psychophysical studies.

Technical Objectives For The Reporting Period

- Continue to coordinate the development of new laboratory facilities for continuation of Pulsed Light projects.
- Assist in research, design, and acquisition or various computer, laser, and stimulus generating software and hardware for new laboratory.
- Develop operational and development workstations for Pulsed Light projects.

**Summary Of Worked Performed During
Current Reporting Period**

- Provided research, design and acquisition of computer hardware and software for new experimental Pulsed Light study.
- Provided consultation in purchasing of electronic equipment for future glare study.
- Provided consultation in purchasing backed projection screens for future glare study.
- Performed as liaison between client, BARCO and Pro-Line Video for development of stimulus interface.
- Developed hardware design for new veiling glare project.
- Provided statistical analysis, interpretation of results, and technical document for Pulsed Laser Light glare project.
- Continued to provide support in the development of the HUD and MFD psychostimulus displays.
- Began development of software/hardware interface using LabView software for new veiling glare study

- Developed experimental workstation for phase I of new study evaluating Contrast Sensitivity.
- Designed experimental protocol for phase I pilot study and performed Contrast Sensitivity experiments.
- Provided statistical and graphical data analysis of phase I pilot experiment.
- Provided client with experimental data analysis, graphical displays and technical support for project defense at annual funding meeting.
- Provided technical report for use in development and presentation of abstracts at Lasers On the Modern Battlefield conference held March 98 at Brooks AFB, Texas.
- Developed software/hardware interface for new veiling glare project.
- Interface was tested and performed successfully.
- Designed and installed bench top component topography for laser operation.
- Installed and successfully tested and ran demonstrations of new 5W Coherent laser for veiling glare project.
- Developed experimental protocol successfully conducted Contrast Sensitivity experiments.

MARES

Description Of Work To Be Performed

- Function as Supply Technician for the Detachment, researching, processing and receiving of orders. Assist other supply technicians within the Detachment in order submission. Complete follow-ups on purchase orders which are beyond the required delivery date. Manage budgetary accounts on all purchases through the base supply departments i.e., Medical supply, Base Supply and the Base service store account. Manage the Plant Property Program on monitoring the major and minor equipment inventory. Assist the Administrative Officer on drafting correspondence between the local supply department and the Detachment. Act as command secretary in the absence of the secretary.

Technical Objectives For This Reporting Period

- Process orders for the Detachment.
- Update purchase orders that are past due.
- Do the monetary budget for base, medical and the base service store.
- Monitor the major and minor equipment inventory.
- Assist the administrative Officer on drafting correspondence between the local supply department and the Detachment.
- Act as command secretary in the absence of the Secretary.
- Assists IMPAC Card Holders in the management of IMPAC.
- Manages Plant Property Inventory of $2,713,315.40.

Summary of Work Performed During Current Reporting Period

- All objectives were met.
- Completed computer training in Excel.

III. NDRI, Great Lakes, IL and NDRI Detachment, Bethesda, MD

A. DENTAL DISEASES-RELATED RESEARCH

BECK

Description Of Work To Be Performed

- Provide technical assistance with ongoing research projects. Participate in National Institute of Dental Research (NIDR) linkage analysis projects. Maintain and upgrade the laboratory such that the research experiments are carried out smoothly. Maintain and record proper technical procedures and data produced for each experiment.

Technical Objectives For The Reporting Period

- Participate in NIDR - Molecular Epidemiology linkage analysis studies of genetic disorders.
- Optimize four bone morphogenic protein (BMP) primer sets and three cytokine primer sets for polymerase chain reactions (PCR).
- Grow and maintain human fibrtoblast cell lines in tissue culture.

Summary Of Work Performed During Current Reporting Period

- Continued to participate in NIDR Molecular Epidemiology projects. These studies deal with the inherited genetic disorders. The most recent completed project dealt with scanning of entire human genome for a potential linkage(s) between screened markers and the genetic disorders such as cleft-lip and palate, Kartagener Syndrome and Early Onset Periodontitis.
- Optimization of each BMP and cytokine primers is completed. In addition, all primers are now being run along with Actin primer set. Actin serves as an internal indicator of how successful the RNA isolations were since all cell types contain message for the Actin product. Thus, by implementing such control will greatly enhance the validity of our experiments while measuring BMP or cytokine messages.
- Human gingival fibroblasts were continuously grown *in vitro* for cytokine level measurements as well as the observation of obvious morphological changes upon stimulating with various denture liners.
- Human gingival and pulpal cell lines were established *in vitro* for the purpose of measuring mRNA levels for specific cytokine proteins via *in situ* hybridization and polymerase chain reactions.

Abstracts:
Abstract submitted and accepted by AADR: "Interlikin-1 Genotypes and Risks of Early Onset Periodontitis"

JONES

Description Of Work To Be Performed

- Senior Research Scientist and Group Leader. Responsible for the Molecular Biological and Molecular Genetic aspects of the projects. This includes the development, evaluation and refinement of molecular biological research protocols.

Technical Objectives For The Reporting Period

- Relative to the program entitled "Biomarkers for Oral Cancer" for the Puerto Rico study subgroup, it is anticipated that SSCP analysis of p53 exons 7 and 9 of the p53 gene will be completed and that DNA sequence analysis using the extended primers will begin.
- Will begin large-scale isolation of DNA from the blood samples received for the Puerto Rico oral cancer case-control study. Will begin the characterization of a number of polymorphic risk-associated genes for these samples.
- Anticipate the continued arrival of specimens from the various sites participating in the VA subgroup of the Biomarkers for Oral cancer study. A tracking database has been established for these samples. Will begin the extraction of DNAs from these materials and the analysis of genetic variation.
- DNAs from the Taiwan Nasopharyngeal Carcinoma Study subgroup will be further characterized using additional genetic markers. A master database of all samples now in hand has been established. Will begin the preparation of these samples for whole-genome mapping in an attempt to identify the gene(s) associated with increased risk for nasopharyngeal carcinoma. The arrival of additional DNA samples for this study is anticipated and these will be incorporated into the ongoing studies.
- Will further characterize the DNAs from the Taiwan Oral Cancer Study subgroup to determine the frequencies of additional polymorphic genesC with special emphasis on those associated with high-risk behavior.

**Summary Of Work Performed During
Current Reporting Period**

- Relative to the program entitled "Biomarkers for Oral Cancer," for the Puerto Rico study subgroup, "first pass" SSCP analysis of exons 5, 6 and 8 of the p53 gene has been completed. "Extended" PCR primers for each of the p53 exons under investigation were designed and the reactions incorporating them are now being optimized. Strategies for the direct sequence analysis of potential mutants are under development.
- Relative to the program entitled "Biomarkers for Oral Cancer," five shipments of DNA for the Taiwan Nasopharyngeal Carcinoma Study have been received to date. The information relevant to these DNAs has been compiled and incorporated into a database in preparation for a large-scale study to identify genes associated with risk for NPC.
- Relative to the program entitled "Biomarkers for Oral Cancer," for the Greek Oral Cancer Study subgroup, additional blood samples, from both case and control individuals, were obtained and the DNA isolated. A characterization of the frequency of polymorphisms within the *CYP2E1, GSTM1* and *GSTT1* genes in the Greek population was carried out and the data submitted for statistical analysis. Further characterization of these DNAs for polymorphisms within a set genetic markers associated with increased cancer risk is in progress.
- Devised an improved allele-specific PCR method for the detection of genetic polymorphisms within the alcohol dehydrogenase 3 (ADH3) gene. Optimization of this method is in progress.
- Relative to the program entitled "Biomarkers for Oral Cancer", samples continue to arrive for the VA Oral Cancer Study subgroup and are presently being archived. For tracking purposes a database of all samples received to date was created. Information on new samples will be added as they arrive.

<u>Publications, Abstracts, etc.</u>
A. Zavras, J.E. Jones, Y-F. Wang, C.W. Douglas and S.R. Diehl. Molecular Epidemiological Investigation of the Etiology of Oral Cancer. Talk presented at the 1998 AADR Annual Meeting in Minneapolis.

MILLER

Description Of Work To Be Performed

- Senior Research Scientist and Group Supervisor. Responsible for all aspects of Immunological, Microbiological, and Tumor Biomarker activities within the Naval Dental School. This includes the development and supervision of research protocols, dental resident mentoring activities, instruction of courses in dental microbiology and dental immunology, serving as a link between NIH sponsored research and Naval Dental Research programs, and troubleshooting of research programs, computers, instrumentation and equipment.

Technical Objectives For The Reporting Period

- Relative to the program entitled "Biomarkers for Oral Cancer," the finial HPV control study to determine assay sensitivities will be completed. Data from the Puerto Rico DNA samples will be evaluated against epidemiological data including smoking incidence. It is anticipated that during the next quarter work will be initiated to evaluate HLA polymorphisms in this group as well as to prepare a manuscript draft. In addition, it is also anticipated that selections will be made to fill the two new positions associated with our tumor biomarkers efforts.
- Relative to the project "Changes in Immunoglobulins as a Result of Smoking Cessation and Relation to Neurotransmitter Genes" funded by NIDR/NIH and jointly conducted by the Navy, Geo-Centers, NIDR, and individuals at the Jerry L. Pettis VA Medical Center in Loma Linda, CA., final blood samples (for a total of 200 subjects) will be collected and evaluated. It is anticipated that all samples will have been collected during the first quarter of 1998. In addition, DNA will continue to be extracted from blood samples in order to begin evaluation of dopamine receptor and transporter gene polymorphisms. In addition, efforts will be made to evaluate cotinine levels in all serum samples. These measurements will help to insure that subjects will be properly identified as to their smoking status.
- Relative to the project "Characterization of Bone Morphogenetic Protein Receptors in Oral Tissues" collection of clinical samples will proceed in preparation for assay.
- Relative to the project concerning the evaluation of cytokine production by oral fibroblasts, optimization of PCR conditions will continue and procedures for *in-situ* hybridization will be developed.
- A new project concerned with a survey of virus associated with periodontal and periradicular infections will be initiated. PCR based procedures will be used to identify specific viral types. During the first quarter of 1978 it is anticipated that PCR conditions will be optimized for several viral DNA samples and that evaluation of some of the clinical samples will have commenced.
- It is anticipated that the course "Oral Immunology" will begin and completed during the first quarter of 1998.

Summary Of Work Performed During Current Reporting Period

- Relative to the program entitled "Biomarkers for Oral Cancer," DNA from Greek study samples have now been extracted and evaluated for genes for the T cell receptor (TCR), p53 exon 8, and HPV-L1. Little evidence for presence of significant HPV DNA was found. The new position for a Scientist I in the Biomarkers program has now been filled.
- Relative to the project "Changes in Immunoglobulins as a Result of Smoking Cessation and Relation to Neurotransmitter Genes" funded by NIDR/NIH and jointly conducted by the Navy, Geo-Centers, NIDR, and individuals at the Jerry L. Pettis VA Medical Center in Loma Linda, CA. To date, 153 subjects have been analyzed. We have found that IgG2 levels significantly decreased among38 subjects who had completely reduced their smoking or had cut back but not quit entirely. We also observed a dose-response relationship between the extent of reduction in smoking and the magnitude of reduction in IgG2. Statistical evaluations of dopamine receptor (DRD2) polymorphism frequencies remain to be completed. An abstract has been submitted and selected for presentation at the Fourth Annual Scientific Sessions of the Society for Research on Nicotine and Tobacco in New Orleans in March.
- Relative to the project concerning the evaluation of cytokine production by oral fibroblasts, work is continuing toward the evaluation of cDNA's obtained from RNA isolated from gingival fibroblasts, pulpal fibroblasts stimulated in culture with a variety of stimulators (TNF, growth factors, and bacterial components). Procedures for *in-situ* hybridization have also been developed. Total RNA has been isolated from frozen clinical periradicular lesion tissue and remains to be reverse transcribed.
- Relative to the project "Characterization of Bone Morphogenetic Protein Receptors in Oral Tissues", collection of clinical samples is continuing. Initial evaluation of BMP-1 mRNA's in periradicular clinical samples has been completed.
- Relative to the studies to evaluate hypersensitivity and cytotoxic effects of soft denture liners, initial studies involving the direct influence of Viscogel (Dentsply), Coe Comfort (GC), FITT (Kerr), Lynal (Caulk/Dentsply), and Coe Soft (Coe Lab) on fibroblast growth have been completed and culture fluids have been evaluated for cytokine levels. In addition, quantitative rt-PCR procedures will be used to measure relative amounts of cytokine mRNA .
- Relative to the survey of viruses associated with periradicular infections, DNA has been secured from 130 clinical samples and evaluated for p53 exon to evaluate DNA quality. Virus assays for HPV, CMV, adenovirus and EBV are being completed.
- The course "Oral Immunology" for dental residents has been successfully completed.

Publications, Abstracts, etc.

Effect of Smoking Cessation on Total Serum IgG. P. O′ Loughlin, G.A. Miller, Y.-F Wang, M. D′ Alesandro, L. Ferry, and S.R. Diehl. Journal of Dental Research, 77-A: 192, 1998. (ABSTRACT)

IV. NMRI TOX/DET Dayton, OH

A. TOXICOLOGICAL STUDIES

ADEMUJOHN

Description Of Work To Be Performed

- The purpose of the neurobehavioral laboratory coordinator at NMRI/TD is to provide technical support to various aspects of ongoing on-site projects in neurobehavioral research. During this quarter the coordinator has been and will be involved in neurobehavioral testing for the effects of simulated stress factors relating to the Gulf War Syndrome on animal models via computer-aided qualitative and quantitative methods. The coordinator also supervises animal training protocols for upcoming pharmaceutical exposure studies.

Technical Objectives For The Reporting Period

The major technical objectives for this quarter is as follows:

- Rangefinding using operant - trained animals and measuring subsequent stages of diminished capacity.
- To compile, catalog and computerize the above mentioned data.
- To train pigeons and rats for problem solving protocols
- To start and complete a drug dose curve on Scopolamine (SCO) on rats
- To compile and analyze previously collected data from the D-Amphetamine, Diazepam, Haloperidol, Diphenylhydantoin studies completed.
- To obtain operant testing and training data for animals used in operant exposure testing.
- To organize, catalog and generate computer graphics, cumulatively from the above-mentioned data.
- To maintain data for future reference in upcoming publications.
- To be responsible for the procurement and securing of all materials used in testing and training protocols.
- Responsible for documenting and maintaining operant weights.
- Responsible for writing and procurement of standard operating procedures for pigeon, rabbit and rat training protocols.
- Responsible for overseeing daily accurate and detailed entries and updates of all work unit laboratory books.
- Responsible for maintaining quality control assurance for all ongoing experiments and/or protocols with / between work unit P. I.'s and laboratory technicians.

Summary Of Work Performed During Current Reporting Period

- Trained and conditioned new and incoming rodent groups to protocol adaptation.
- Maintenance of all laboratory work unit notebooks
- Implemented several data methods to compile training data and weight maintenance on the all operants.
- Compiled stock animal drug history logs
- Compiling meeting memorandums for the OIC
- Trained all incoming personnel on standard procedures for lab techniques.
- Analyzed and compiled data on D-Amphetamine, Diazepam, Haloperidol, and Diphenylhydantoin to present a poster presentation on Drug Study Results.

Presentations:

- Ademujohn, C.Y., CDR John Rossi III, Glenn Ritchie, PhD., And LT A.F. Nord holm, MSC. USNR, **Predictive Validation of the Neurobehavioral Toxicity Assessment Battery (NTAB):** The **Progressive Ratio Test Of Motivational System Integrity**. Naval Medical Research Institute Detachment-Toxicology (NMRI/TD) & Geo-Centers, Inc., 2612 Fifth St. Building 433, Wright-Patterson AFB. OH, 45433-7903.*Conference on Issues and Applications in Toxicology and Risk Assessment March, 1998.*
- Ritchie, GD, Ademujohn, CY, MacInturf, S, Hulme, ME, McCool, C, Nordholm, AF, Rossi III, J, MacMahon, K, Leahy, H, and Wolfe, RE. Repeated Exposure of Rats to JP-4 Vapor Induces Changes in Neurobehavioral Capacity and 5-HT/5-HIAA Levels.
- Effects of Human Anti-Epileptic Drugs And/Or GABA-B Antagonist CGP-35348 on TMPP-I nduced EEG Paroxysms. Glenn D. Ritchie[2], CDR John Rossi III, MSC, USN[1], LT Alan F. Nordholm, MSC, USNR[1], Mary E.Hulme[2], Cynthia Y. Ademujohn[2] and Jeffrey Cassell[1], Naval Medical Research Institute Detachment-Toxicology[1] and Geo-Centers, Inc.,[2] Wright Patterson Air Force Base, Ohio. Abstract & Poster, NEHC Conference, San Diego, CA, Mar 1998.

BRIGGS

Description Of Work To Be Performed

- Dr. Briggs is the General Manager and Senior Contractor Representative for Geo-Centers, Inc., for the NMRI contract at the Toxicology Detachment (NMRI/TD). He serves as a member of the Executive Steering Committee and performs toxicology research as an Associate Investigator. He is responsible for collaborating Geo-Centers, Inc. resources in support of the toxicology research in support of the NMRI/TD mission. Dr. Briggs functions in response to taskings from the Officer-In-Charge of the Detachment.

Technical Objectives For The Reporting Period

- Continue to assist in providing Contractor resources to support toxicology research and meet project milestones. This includes planning, collaborating, providing technical support and ensuring that data are presented in a timely manner.
- Perform research as tasked by the O.I.C. These tasks focus primarily on human health risk assessment and toxicity of the reproductive, endocrine and immune system.
- Provide quality assurance support for the Quality Management Program. This includes functions to maintain the quality and integrity of data collected and presented by the staff at NMRI/TD.

Summary Of Work Performed During Current Reporting Period

- Assisted Management in preparing transition documents and reports to help ensure a smooth transition from NMRI to NHRC. This included preparing and reviewing year end reports and technical briefings to inform Customers of project and program status. Performed planning guidance and strategic resource deployment to support current and emerging technologies.
- Provided input into marketing efforts directly with new sponsors and at the Society of Toxicology Meeting, NEHC, JANNF and the WPAFB Spring Meeting.
- Procured the sperm analyzer and set it up and validated it to perform reproductive system risk assessment from rats and rabbits. Supervised the training and performed the initial validation of the methods and equipment
- Reviewed an Endocrine Disruptors position paper for Management and submitted comments for action. Attended the NIH/NIEHS Endocrine disruptors meeting and represented the O.I.C. on a breakout group for advising the host organizations on promulgation of the Food Quality Protection Act and Clean Air Act provisions for endocrine disruption.
- Conducted two Quality Management Program inspections of Administrative functions. Prepared the final Standard Operating Procedures and ensured that new SOPs were properly updated.

- Assisted in the development of the Respiratory Protection Plan and ensured compliance with all regulations and guidelines.
- Attended the Society of Toxicology Meeting, the Spring Conference at WPAFB and 2 meetings relating to reproductive toxicology.
- Gained Adjunct Assistant Professor status in the Medical School at Wright State University

Publications, Abstracts, etc.
Prepared and presented 2 posters at NEHC and the Spring Conference at WPAFB. (Emerging Issues for Endocrine Disrupting Chemicals in Naval Operations and The Use of Risk Assessment in Navy Deployment Toxicology--This poster was judged to be the Best Information Poster at the NEHC Meeting.)

CONNOLLY

Description Of Work To Be Performed

- Cataloging print and non-print materials for circulation
- Ordering and maintaining serials collection, including claiming missing issues
- Handling reference questions
- Providing interlibrary loan assistance
- Locating needed materials in other libraries
- Preparing book orders

Technical Objectives For The Reporting Period

- Catalog materials as received
- Catalog materials not yet cataloged
- Provide library service to the toxicology community at WPAFB
- Continue working on a manual card catalog
- Continue improving card catalog in Access

Summary Of Work Performed During Current

- 104 articles obtained from local libraries
- 2 books borrowed from local libraries for customers here
- 4 interlibrary loans obtained
- 2 interlibrary loans provided to another library
- 6 literature searches conducted using in-house CD/ROM database capabilities
- 7 searches successfully conducted on the Internet for customers, including downloading of documents as required
- 8 reference questions answered

- 5 telephone inquiries on journal locations in local area handled successfully
- 12 requests for articles located and filled from in house resources
- 4 orientation/training sessions conducted
- journal volumes consulted by customers – program crashed so figures were lost
- 23 new books cataloged and prepared for circulation
- 584 card sets typed

HORTON, DIBLEY

Description Of Work To Be Performed

- Maintain Local Area Network (LAN)
- Maintain and upgrade individual Desktop and Laboratory Computers
- Provide answers, support and expertise in correcting computer problems, including all peripherals attached to these systems
- Continue comprehensive program for maintaining system integration and reliability through back-up procedures, documentation, and redundant systems
- Continue to update information Databases IRIS, Medline, Toxline and Serline
- Organize Media, Manuals and Spare Parts
- Prepare ASDPs for procurement of new computer systems, software and peripherals
- Assist with creation and development of professional presentations by staff scientists
- Maintain in-house software and databases

Technical Objectives For The Reporting Period

- Continued planning for and implementation stages for addition of VA to our LAN, including physically surveying site for wiring and connections.
- Incorporate standardized ADP SOPs into ADP SOP manual as needed
- Continue to develop on-line user SOP via our Exchange system

Summary Of Work Performed During Current Reporting Period

- Completed hardware repairs of "Defiant" RAS server.
- Installed and configured STARS-FL for Administrative Officer
- Reviewed and assisted with installation of new computerized sperm analyzer
- Procured software solution to manipulate graphical data from APS instrument.
- Updated Service Packs and Hot Fixes as needed on Network Servers
- Ordered various software and hardware upgrades
- Continued to reconfigure Windows Browser and WINS for WAN as needed

- Continued maintenance of Servers including backing up data files
- Continued support of hardware and software for TOXDET personnel
- Continued to update information Databases
- Continued development of ADP SOP manual - this is an ongoing process that will assist NMRI/TD to meet GALP guidelines

JUNG

Description of Work to Be Performed

- Responsible for providing technical support to specific on-going projects for toxicology research. These projects include:

Trimethylolpropane (TMPP) Evaluation
- Determination of the toxicity of TMPP, a thermal decomposition product of aviation engine lubricants.

DBNP
- Determination of the toxicology of a material found in submarine environments.

Drug Distribution Study
- Studies to measure the rate at which five drugs reach the brain using a microdialysis technique.

JP-8 Fuel Project
- Determination of the toxicity of jet fuels and other similar compounds of fleet importance.

General
- Attend courses and meetings to present findings and learn new methods and research techniques.

Technical Objectives for The Reporting Period

TMPP Evaluation
- Complete all corrections to the recently reviewed paper and resubmitted it.

DBNP
- Complete all corrections to the recently reviewed paper and resubmitted it.

Drug Distribution Study
- Locate the HPLC methods for the detection of the five different drugs
- Do preliminary test of the feasibility of the placement of the microdialysis probes

JP-8 Fuel Project
- Standardize the GC method by which JP-8 fuel will be quantitated

Summary Of Work Performed During Current Reporting Period

TMPP
- A paper was written on the results of neurotransmitter concentration analysis and has been sent to a journal for review. HPLC analysis of the levels of amino acids in TMPP exposed rat brains was completed and the analysis of the data completed. The paper written by Dr. Lindsey was accepted and will be published by the Journal of Toxicology and Environmental Health.

DBNP
- The paper, "Acute Toxicity, Kinetics, and Metabolic Investigation of 2,6-Di-tertiary-butyl-4-nitrophenol in Fischer-344 rats" by TK Narayanan, A. E. Jung, S. L. Prues, R. L. Carpenter and K. R. Still was submitted to Toxicology Letters, which reviewed it and returned it for corrections. Corrections are in the process of being completed.

Drug Distribution Study
- A preliminary test of the study was conducted. Two microdialysis probes were surgically implanted into the brain of an anesthetized rat to measure the amount of diazepam in those regions of the brain. After equilibration, the rat was dosed with diazepam and the amount present in aliquots taken from the brain was measured. Two rats have been run, a high and low dose. The process of working out the problems in method have begun.

General
- Attended the Conference on Issues and Applications in Toxicology and Risk Assessment, April 27-30, 1998 at the Hope Hotel Wright-Patterson Air Force Base, OH.

JP-8 Fuel Project
- The standardization of the detection and quantification of JP-8 fuel by Perkin-Elmer GC was begun. Samples of JP8 jet fuel were run on the Perkin-Elmer GC and a standard curve is being collected.

Publications, Abstracts,etc.

- "Acute Toxicity, Kinetics, and Metabolic Investigation of 2,6-Di-tertiary-butyl-4-nitrophenol in Fischer-344 rats" TK Narayanan, A. E. Jung, S. L. Prues, R. L. Carpenter and K. R. Still.

Submitted Toxicology Letters

- "Tissue Distribution, Metabolism, and Clearance of Trimethylolpropanephosphate (TMPP) in Fischer-344 Rats" Tanjore K. Narayanan, Anne E. Jung, Glenn D. Ritchie, John F. Wyman, and John Rossi III.
- "Acute Effects of a Bicyclophosphate Neuroconvulsant on Monoamine Neurotransmitter and metabolite Levels in the Rat Brain" James W. Lindsey, Anne E. Jung, Tanjore K. Narayanan, Glenn D. Ritchie; Journal of Toxicology and Environmental Health, Part A, 54: 101-109, 1998.

KIMMEL, REBOULET, WHITEHEAD

Description Of Work To Be Performed

- This group is responsible for the design, construction and operation of systems to conduct inhalation toxicity studies. We also are perform a variety of assays of pulmonary toxicity. Our present research focus is the development and exploitation of small animal models of Acute Lung Injury (ALI) and it's more severe form Acute Respiratory Distress Syndrome (ARDS) as induced by inhalation of combustion atmospheres and surrogate combustion atmospheres. We have developed inhalation exposure systems ranging from highly instrumented, single animal, nose-only exposure chambers suitable for inhalation dosimetry studies to a large (690 L) whole-body inhalation exposure chamber. We also have and continue to develop methods to measure small animal pulmonary function and perform histopathological analysis of pulmonary tissue samples.

Technical Objectives for The Reporting Period

- Develop methods to analyze ventilation and pulmonary mechanics in six animals simultaneously and in real time during an exposure.
- Develop an exposure system to expose single animals (nose-only) with a non-rebreathing valve in line
- Develop and perform battery of small animal pulmonary function tests using a pressure type plethysmograph,
- Develop protocol for experiments to verify a mathematical model of hyperventilation induced by CO_2.

Summary Of Work Performed During Current Reporting Period

- Start and finish implementation of final battery of small animal Pfts for future research. This includes the complete battery of forced expiratory maneuvers and N2 washout techniques.
- Conduct an experiment needed to verify mathematical model (logistic model using - physiologic constants) of CO_2 induced hyperventilation in animals. This model will be used for risk assessment and prediction of increased dosimetry to other toxins in complex atmospheres which contain CO_2.
- Completed first draft of manuscript on the development of a new plethysmographic technique - to J of Applied Physiology
- Completed first draft of technical reports on measurement of small pulmonary function in NMRI/TD system. Will do a series of reports describing fundamentally different techniques -- at present 2 reports have been started addressing barometric methods and a second flow plethysmographic methods for determination of ventilation and dynamic mechanics of breathing.
- Finalized manuscript describing an small scale in expensive solid material combustion furnace for laboratory combustion toxicology studies that was developed by our group - submission to J Fire Sciences.
- Completed ARDS phase three protocol - effects of NOx

<u>Publications, Abstracts, etc.</u>

- Kimmel EC, Smith EA, Carpenter RL, Reboulet JE, and Black BH. Comparison of the potential risk for inhalation toxicity between laboratory and field generated atmospheres of a dry powder fire suppressant (Submitted - *Inh. Tox - accepted -in revision*).
- Kimmel EC, Carpenter RL, Smith EA, Reboulet JE, and Black BH. 1998. Physiologic models for comparison of inhalation risk between laboratory and field generated atmospheres of a dry powder fire suppressant. *Inhal Tox.* accepted - in revision
- Kimmel EC, Carpenter RL, Reboulet JE, and Still KR. A physiologic model of carboxyhemoglobin formation in rats by inhalation of carbon monoxide. Submitted *J. Appl. Physiol.*
- Kimmel EC, Reboulet JE and Carpenter RL. Inhalation exposure chamber leak rate determination with thermal correction. (*Am Ind. Hygiene Assoc. J.* - in press).
- Reboulet, JE, Kimmel EC and Carpenter RL. A basic computer program for rapid standard bag calculations. (*Tox. Methods* - resubmitted*). * New Editor for the Journal recanted acknowledgment of previous editors receipt of the manuscript.
- Kimmel EC, and Still KR. Acute lung injury, acute respiratory distress syndrome, and inhalation injury: A brief overview. - submitted to *Drug and Chemical Toxicology*

Publications in draft

- Kimmel, Reboulet, Narayanan, Carpenter. The Effects of co-exposure with aerosol particles on acrolein inhalation toxicity. *Toxicol Sci.*
- Kimmel. A head out plethysmograph for measurement of intrapleural pressure and determination of pulmonary mechanics in small animals during inhalation exposure without surgical intervention. *J Appl Physiol.*

Technical Reports in press

- Kimmel EC, Smith EA, Reboulet JE, Still KR, and Carpenter RL. 1997. The physicochemical properties of sfe fire suppressant atmospheres in toxicity vs. fire extinguishment tests: Implications for aerosol deposition and toxicity. 43pp.
- Kimmel EC, and Still KR. 1997. The acute respiratory distress syndrome (ARDS) and militarily relevant inhalation injury: A brief review., 88pp.
- Reboulet JE, and Kimmel EC. 1998 - An inexpensive, furnace for small scale combustion toxicology studies - 22 pp.

MCINTURF

Description Of Work To Be Performed

- Serves as the research design and analysis assistant for the Neurobehavioral Group at the NMRI/TD, and as a primary research technician for all currently funded neurobehavioral research.
- Assists in the design, data collection, and analysis for many of the neurobehavioral studies, and with the fabrication, setup, and operation of hardware/software and other instrumentation for data collection.

Technical Objectives For The Reporting Period

- To complete the collection and analysis of data from the rabbit eyeblink conditioning study. Currently, this study evaluates the effects of neurotoxins (TMPP & PTZ) on conditioned response and/or learning and memory. The study also focuses on identifying possible counteractive or preventive capacities that well known human anticonvulsant agents (Diazepam) may have on neurotoxins.
- To collect and analyze data for a study of exposure to TMPP and antilconvulsant agents on seizure activity in rats.

- Complete design of Morris-like water maze experiment to be used in up-coming neurobehavioral study (as part of the NTAB) involving neurotoxins and possible counteracting drugs.
- Offer assistance in histopathology for rats from the Inter Cranial Self Stimulation Study (ICSS) currently being conducted at the Veterans Administration.
- Continue familiarization of program languages used with current hardware (particularly MED-PC notation) in order to write programs and macros for operant and other studies.
- Continue to offer research design and data analysis assistance with the use of statistical software packages.
- To complete relocation of the NMRI/TD Neurobehavioral Laboratory to the Research Facility of the Veterans' Administration Hospital, Dayton, OH.
- Take over pigeon operant training and continue drug curves for ongoing study.

Summary Of Work Performed During current Reporting Period

- Completed collection and analysis of data for entire sample of the rabbit eyeblink conditioning study involving TMPP and Diazepam. Assisted in the early stages of writing the eyeblink paper. Completed poster presentation.
- Attended Conference on Issues and Applications in Toxicology and Risk Assessment being held at the Hope Hotel at Wright Patterson Air Force Base. Poster presentation title: The Navy Neurobehavioral Assessment Battery (NTAB): The Effects of TMPP, PTZ, and Diazepam on the Conditioned Eyeblink Response, A Simple Form of Learning.
- Began initial testing of software/hardware for Morris-like water maze pool.
- Setup and operation of all hardware and instruments for acoustic startle and conditioned
- eyeblink response.
- Completed literature surveys on eyeblink, jet-fuel, acoustic startle, and water maze as
- relevant to NMRI/TD research.
- Continued familiarization of programming languages and a variety of software
- applications that run on many of the data collecting instruments.

<u>Presentations, Abstracts, etc.</u>

- Nordholm, A., Ritchie, G., MacMahon, K., McInturf, S., Hulme, M.B and Rossi III, J. Acute and long-term consequences from repeated exposure of rats to JP-4 jet fuel and/or stress. Abstract, Society of Toxicology, Annual Meeting, Seattle, WA, 1998.
- McInturf, S., Hulme, M.B, Ritchie, G., and Nordholm, A. The Navy Neurobehavioral Assessment Battery (NTAB): The Effects of TMPP, PTZ, and Diazepam on the Conditioned Eyeblink Response, A Simple Form of Learning. Abstract, Conference on Issues and Applications in Toxicology and Risk Assessment, Wright Patterson Air Force Base, OH, 1998.

HULME

Description Of Work To Be Performed

- Serves as the research design and analysis assistant for the Neurobehavioral Group at the NMRI/TD, and as a primary research technician for all currently funded neurobehavioral research.
- Assist in the design, data collection, and analysis for many of the neurobehavioral studies, and with the fabrication, setup, and operation of hardware/software and other instrumentation for data collection.

Technical Objectives For The Reporting Period

- To continue the collection and analysis of data from the roto-wheel and grip strength study. Currently these studies evaluate the effects of Diazepam, Scopolamine, and Ethanol on motor system integrity and endurance.
- To collect and analyze the data from the Opto-Verimax study, using TMPP, and PTZ.
- To collect and analyze the data from the anit-convulsant study. Five anit-convulsants will be evaluated on TMPP induced rats.
- Present poster at the Conference on Issues and Applications in Toxicology and Risk Assessment titled, "Validation of NTAB Roto-wheel and Forelimb Grip Strength Test Using Diazepam or Ethanol to Measure Motor System Integrity and Endurance".
- To inject 40 rats with TMPP for sperm analysis.

Summary Of Work Performed During Current Reporting Period

- Completed the analysis of data for roto-wheel and grip strength tests using Diazepam, and Ethanol.
- Completed Diazepam drug curve for operant pigeons, and analyzed the data.
- Completed literature surveys on jet-fuel, grip strength, eye-blink, and roto-wheel as relevant to NMRI/TD research.
- Presented poster at the Conference on Issues and Applications in Toxicology and Risk Assessment titled, "Validation of NTAB Roto-wheel and Forelimb Grip Strength Test Using Diazepam or Ethanol to Measure Motor System Integrity and Endurance".

Presentations, Abstracts, etc.

- Ritchie, G.D., Hulme, M.E., Nordholm, A.F., and Rossi III, J. Effects of GABA-B antagonist CGP-35348 and human anti-epileptic drugs on spontaneous and chemically-induced absence-like SWD's in Fisher-344 rats. *Epilepsia,* In preparation.
- Ritchie, G.D., McInturf, S., Hulme, M.E., McCool, C. Repeated exposure of rats to JP-4 jet fuel vapor induces changes in neurobehavioral capacity and 5-HT/5-HIAA levels. *Toxicology and Environmental Health*, In Preparation
- M Hulme, S. McInturf, G. Ritchie, and A. Nordholm. "Validation of NTAB Roto-wheel and Forelimb Grip Strength Test Using Diazepam or Ethanol to Measure Motor System Integrity and Endurance". (Poster Presentation)
- S. McInturf, M. Hulme, G. Ritchie, and A. Nordholm. "Application of the neurobehavioral toxicity assessment battery (ntab): the effects of tmpp,ptz and diazepam on the conditioned eyeblink response, a simple form of learning. (Poster Presentation)

SMITH, PRUES

Description Of Work To Be Performed

- Conduct/ design /oversee studies addressing Navy related research issues.
- Provide necessary paperwork for the accounting of project funding
- Maintain GLP compliant data books on those studies with which there is personal involvement.
- Submit articles/revisions for publication of project findings to peer-reviewed journals.
- Submission of timely progress reports

Technical Objectives For The Reporting Period

New Methods in Physiological Based Pharmacokinetic Modeling

- The objective of this research is to develop new methods of obtaining data for PBPK modeling while reducing the number of animals needed to conduct certain traditional toxicology studies (ADME studies).

Cardiac Sensitization

- The objective of this research is to develop a model for the determination of cardiac sensitization. These initial studies will set the basic background needed for future studies.

Trimethylopropane phosphate (TMPP)

- The objective of this research is to determine the mechanism of action of TMPP. TMPP is a by-product from the breakdown of synthetic lubricants that produces a neurotoxic response.
- Contract Representative on the Safety Policy Committee (Sue Prues)
  The objective of this duty is to act as liaison between the Navy and Geo-Centers personnel in addressing the concerns of workplace related safety issues.
- Respiratory Protection Program Manager (Sue Prues)
  Assist in setup, operation and maintenance of the NMRI/TD Respiratory Protection Program.

Summary Of Work Performed During Current Reporting Period

PBPK modeling -- Homeostasis

- Completed a pulmonary inhalation study involving carbon monoxide (CO).

TMPP Project -- Glial Fibrillary Acidic Protein (GFAP)

- Protein assay and determination of standard units.

Intercranial Selfstimulation (ICSS)

- Ran a drug curve on the rats with EEG electrode implants.

Neuropharmacology Study

- Demonstrated and supervised several surgeries involving the stereotaxic implantation of CMA microdialysis probes.

General

- Provide assistance/training for projects requiring drug preparation, surgical implantation of devices via stereotaxic methodology, etc. as needed

Respiratory Protection Program

- Submitted a written Respiratory Protection Program designed to comply with the new OSHA 1910.139.
- Creating lesson plans for training and maintenance sessions for use during preliminary training sessions.
- Designed and included in the written program: schedules/logs to document usage as well as record sheets for documentation of scheduled equipment maintenance.

Publications, Abstracts, etc.

- Comparison of Toxicity after Exposure to Two Formulations of SFE Formulation A. Eldon A. Smith, Edgar C. Kimmel, James E. Reboulet, Susan L. Prues, and Robert L. Carpenter, Fundamental and Applied Toxicology (in review).

RITCHIE

- Serves as Assistant Group Leader for the Neurobehavioral Toxicology Group at the Tri-Service Toxicology Consortium and NMRI/TD and as Associate Principal Investigator (API) for all currently funded neurobehavioral toxicology-related work units (FY'98 funding of $850K+).
- Assists in all areas of program management, budgetary control and procurement, research design, protocol preparation, research supervision, statistical analysis and preparation of scientific papers and abstracts in the area of neurobehavioral toxicology research.

Description Of Work To Be Performed

<u>TMPP Mechanisms of Action:</u>

- Development of Neurobehavioral Molecularization Techniques (WU .1516): anatomical disposition and neurobehavioral effects of trimethylolpropane phosphate (TMPP), a potent neurotoxicant produced through the pyrolysis of synthetic lubricants used in military ships and aircraft.

<u>Mechanisms Involved with Exposure to Select Neurotoxicants (WU .1712):</u>

- Development, testing and validation of new physiological and mathematical modeling techniques for estimation of expected concentrations of selected toxicants in major CNS regions following dermal, oral or respiratory exposures.

<u>Development of the Navy Neuro-Molecular Assessment System (the NTAS) [WU .1713]:</u>

- Development and validation of a number of neuro-molecular (cellular-level) analytical techniques for eventual inclusion in the NTAS.

<u>Neurobehavioral Toxicity Assessment Battery (NTAB):</u>

- Assessing Animal Responses to Pharmacological Challenge (WU .1605): Predictive validation of the NTAB by comparison of animal and (known) human responses to identical pharmacological challenges on neurobehavioral tests with topographical similarity.

<u>Comparative Neurobehavioral Toxicity Assessment of Three Hydrocarbon Fuels. U.S. Army Medical Research and Materiel Command funding (WU .1807).</u>

- Comparison of the relative neurobehavioral toxicity of repeated exposure of rats to low concentrations of JP-8 or JP-5 jet fuel, or diesel fuel vapor.

Technical Objectives For The Reporting Period

- To arrange meeting with CEREP Corp (France) for contract neurotransmitter assay.
- To present SOT, NEHC and Hope Hotel Conference abstracts and posters on TMPP effects.
- To conduct major study evaluating effects of phenobarbital, diazepam, tiagabine, DNQX, scopalamine on preventing TMPP-induced seizures.
- To conduct study evaluating the effects of TMPP, pentylenetetrazol, or vehicle on general locomotor activity in rats.
- To submit manuscript (Rossi et al) reporting the Disposition, Metabolism and Clearance of TMPP.
- To complete manuscript from a major study evaluating the relative capacities of well known human anticonvulsant agents to prevent or counteract EEG paroxysms induced by low doses of TMPP.
- To oversee beginning of contracted work at USC investigating ligand binding of TMPP.
- To complete study of TMPP induced effects on eyeblink classical conditioning in the rabbit.
- To continue tissue slice evaluation of TMPP effects on single unit and membrane responses in the rat hippocampus.
- To submit Society for Neuroscience abstracts (2) on TMPP effects and abstract for GABA-B Conference
- To submit WPAFB and WSU IACUC protocols for the use of microdialysis and EEG analysis in evaluating the uptake and regional CNS deposition of several pharmacologically active compounds.
- To begin pilot study of the quantification of ip administered TMPP or diazepam using intracranial microdialysis.
- To complete transition of microdialysis system from Dr. Lindsey to Anne Jung
- To work to Dr. Fischer (USAF) to arrange mathematical PBPK/PBPD modeling of results.
- To work with Dr. Jan Lin in development of methods and techniques for hippocampal tissue slice.
- To work with Dr. Eldon Smith & Dr. Cody Wilson for development of quantitative techniques for analysis of neuroprotein markers (i.e., cFOS, GFAP) in response to toxic insult.
- To present SOT, NEHC and Hope Hotel Conference abstracts and posters
- To validate four component tests of the NTAB battery using rats. Following challenge with three doses levels of nine pharmaceutical drugs (i.e., ethanol, diazepam, etc.), animals will be evaluated on the Porsolt Forced Swim Test, Morris Water Maze, and Navy Roto-Wheel/Accelerod.
- To work with Dr. Alan Nordholm in conditioned eyeblink classical conditioning rabbits and human subjects.
- To complete operant training of 21 pigeons to be used in validation of NTAB tests involving visual discrimination, higher cognitive function and physiologic irritancy.

- To begin development of human tests to be included in the GASH battery (i.e., operant conditioning, auditory startle, eyeblink classical conditioning, etc.) to be compared to NTAB tests for predictive validation.
- To work with the Veterans Administration Hospital (Dayton, OH) for use of PTSD patient population for initial NTAB testing.
- To present SOT, NEHC and Hope Hotel Conference posters
- To write manuscript using NTAB to evaluate neurobehavioral toxicity of HFC-134a.
- To arrange Wash, DC meeting with Dr. Bernie Weiss, Dr. Richard Thompson, Dr. Robert Russell, Dr. Peter Dews and Dr. Doull to complete revision of the 28-year plan for The Neurobehavioral Toxicology Thrust Area for Military Deployment Toxicology.
- To work with Dr. Carpenter in complete set-up of the NMRI/TD Inhalation Exposure Laboratory for JP-8 exposures.
- To select neurobehavioral tests for evaluation of exposed rats.
- To complete manuscript reporting effects of repeated exposure to low levels of JP-4 vapor and/or stress on neurobehavioral capacity in rats.
- To prepare platform presentation/slides for Joint Services Program Evaluation Committee and JANNAF presentations on jet fuel toxicity.
- To submit abstract to the DoD Persian Gulf Researchers Meeting in Wash, DC (June 17-19)

Summary Of Work Performed During Current Reporting Period

- Completed meeting with CEREP Corp (France) for contract neurotransmitter assay.
- Presented SOT, NEHC and Hope Hotel Conference abstracts and posters on TMPP effects.
- Conduced major study evaluating effects of phenobarbital, diazepam, tiagabine, DNQX, scopalamine on preventing TMPP-induced seizures.
- Conducted study evaluating the effects of TMPP, pentylenetetrazol, or vehicle on general locomotor activity in rats.
- Completed study of TMPP induced effects on eyeblink classical conditioning in the rabbit.
- Completed revisions required for acceptance for publication (Lindsey et al) of manuscript examining TMPP-induced changes in regional CNS neurotransmitter levels in the rat.
- Completed revisions required for acceptance for manuscript (Lin et al) examining TMPP-induced sensitization of rat limbic system
- Began supervision of contacted work with Dr. Thompson's Laboratory to examine ligand binding of TMPP.
- Submitted manuscript (Rossi et al) reporting the Uptake, Deposition, Metabolism and Clearance of TMPP.
- Completed manuscript of a major study evaluating the relative capacities of well known human anticonvulsant agents to prevent or counteract neurotoxicity induced by exposure to low or high doses of trimethylolpropane phosphate.
- Presented SOT, NEHC and Hope Hotel Conference posters.

- Submitted two (2) SON abstracts and one SON abstract
- Gained approval of WPAFB and WSU IACUC protocols for the use of microdialysis and EEG analysis in evaluating the uptake and regional CNS deposition of several pharmacologically active compounds.
- Began pilot study of the quantification of ip administered TMPP or diazepam using intracranial microdialysis.
- Completed transition of microdialysis system from Dr. Lindsey to Anne Jung
- Met with Dr. Fischer (USAF) to arrange mathematical PBPK/PBPD modeling of results.
- Worked with Dr. Jan Lin in analysis of data from hippocampal tissue slice/TMPP study
- Worked with Dr. Eldon Smith & Dr. Cody Wilson for development of quantitative techniques for analysis of neuroprotein markers (i.e., cFOS, GFAP) in response to toxic insult
- Presented SOT, NEHC and Hope Hotel Conference posters.
- Completed 50% of the validation of four component tests of the NTAB battery using rats. Following challenge with three doses levels of nine pharmaceutical drugs (i.e., ethanol, diazepam, etc.), animals will be evaluated on the Porsolt Forced Swim Test, Morris Water Maze, and Navy Roto-Wheel/Accelerod.
- Completed, with Dr. Alan Nordholm, initial studies of the conditioned eyeblink classical conditioning in rabbits.
- Continued operant testing of 21 pigeons, following PCP or amphetamine administration, related to validation of NTAB tests involving visual discrimination, higher cognitive function and physiologic irritancy.
- Began development of human tests to be included in the GASH battery (i.e., operant conditioning, auditory startle, eyeblink classical conditioning, etc.) to be compared to NTAB tests for predictive validation. To work with the Veterans Administration Hospital (Dayton, OH) for use of PTSD patient population for initial NTAB testing.
- Presented SOT, NEHC and Hope Hotel Conference posters
- Completed manuscript using NTAB to evaluate neurobehavioral toxicity of HFC-134a.
- Arranged Jul 1998 Wash, DC meeting with Dr. Bernie Weiss, Dr. Richard Thompson, Dr. Richard Russell, Dr. Peter Dews and Dr. Doull to complete revision of the 28-year plan for The Neurobehavioral Toxicology Thrust Area for Military Deployment Toxicology.
- Continued research to validate four component tests of the NTAB battery using rats.
- Completed set-up of the NMRI/TD Inhalation Exposure Laboratory for JP-8 exposures.
- Selected neurobehavioral tests for evaluation of exposed rats.
- Completed manuscript reporting effects of repeated exposure to low levels of JP-4 vapor and/or stress on neurobehavioral capacity in rats.
- Presented platform presentation at Joint Services Program Evaluation Committee and JANNAF presentations on jet fuel toxicity.
- Submitted abstract to the DoD Persian Gulf Researchers Meeting in Wash, DC (June 17-19)

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- Bekkedal, M.Y.V., Panksepp, J. and Rossi III, J. Long-term changes in rat social behavior following treatment with trimethylolpropane. *Neurotoxicol. Teratol.*, in press, 1998.
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V. NMRI, Natick, MA

A. HUMAN PERFORMANCE AND U.S. NAVY CLOTHING DEVELOPMENT

GC-TR-3117-030

FINAL TECHNICAL REPORT

TECHNICAL SUPPORT
to the
NAVY CLOTHING
and
TEXTILE RESEARCH FACILITY
(NCTRF)

Prepared For

U.S. Navy Clothing and Textile Research Facility
P.O. Box 59
Natick, MA 01760
Under Contract No. N00014-95-D0048/0004, Task No. 3117-030

Prepared By

GEO-CENTERS, INC.
7 Wells Avenue
Newton, MA 01259

June 1998

GEO-CENTERS, INC.

Program I: Flame Protective Clothing Research *(Pawar)*

Subtask 1: Flame Protection

- The math modeling project involved work at the University of Texas on mathematical simulation of human thermal behavior using whole body model. The detail discussion of this approach was found in the 'Heat transfer in medicine and biology: analysis and applications.' The main tasks in this project were to understand the working of the FORTRAN program software, its input parameters, learn the method of creating input file, and execute the simulation runs to get meaningful results.
- Evaluation of response of copper calorimeter at various heat fluxes on the automated TPP Test equipment was another research objective. This task is a continuation of the Thermal Protection Analysis System previously developed. The TPA system can be used as a convenient method for calibrating copper calorimeters to satisfy second-degree burn criterion developed by Stoll et al. It was required to develop an extension for the heat gun to keep it at a fixed distance from the surface under heating.
- Designed a method and equipment for calibration of the copper calorimeter under various heat exposure levels.
- Research was performed on the relationship between the degree of burn injury and the probability of survival of a victim. Research was also performed on the manikin diagram and an appropriate file format for such a diagram. National Instruments suggested using "Canvas Control" from their software development package for creation of controls for the manikin diagram.
- Developed a method to characterize thermal response of a copper calorimeter and that of a sensor with embedded thermocouple.
- Developed a prototype data acquisition system for the above method.
- Worked on the development of thermal response for three types of sensors. These sensors are nonstandard copper calorimeter, skin simulant and the commercial radiometer. This system should be useful in making the correct sensor choice for different fire risks.
- Designed the program structure. Designed all interface elements. Worked on reconfiguring the hardware for multi-channel data acquisition. Tested the configuration for its accuracy.
- Prepared the final report and test instruction manual which were delivered to the NCTRF Project Officer.

Subtask 2: Heat Stress Protection

- Use of finite vapor pressure and latent heat of vaporization has been used in microclimate cooling. The cooling of garments on an equal basis i.e., independent of microclimate cooling systems is being investigated. Performance equations for such garments are also being developed. The research interest created a need for developing a data acquisition system to measure temperatures, pressures and flow rates in experiments.

- Designed graphic user-interface for the microclimate cooling system.
- A prototype of graphic user interface (GUI) was created for evaluating the microclimate cooling systems used in manikin tests. A study was conducted in-house on pressure transducers, flow rate transducers and circulating chillers for interfacing with computers.

Subtask 3: Cold Water Immersion Protection

- Studied the predictive capability of the Texas Human Thermal Model (also known as the Wissler Model) during cold water immersion for given garments.
- Performed an analysis of cold water immersion data on human subjects from Steinman.
- Analyzed the simulation results for predicting the skin and the rectal temperatures under cold water, for float coat and the standard anti-exposure suit.
- Completed the data analysis for calm seas. Summarized data on eight human subjects in rough seas.

Program II: U.S. Navy Certification Program for Commercial Environmental/Occupational (CEO) Protective Clothing/Equipment ***(Macek)***

- GEO-CENTERS, INC. established a procedure to be used by U.S. Navy Clothing & Textile Facility (NCTRF) to certify commercial off-the-shelf protective clothing/equipment as meeting or exceeding Navy functional performance requirements. This procedure will make possible the direct purchase of certified commercial protective clothing/equipment for shipboard use by Navy personnel.
- A draft report was submitted to NCTRF for review and comments.

Program III: Database Search ***(Macek, Collins, Smith)***

- GEO-CENTERS, INC. conducted an extensive search of databases to determine commercial, DoD and non-DoD government organizations with which the U.S. Navy Clothing & Textile Facility (NCTRF) may enter into cooperative R&D agreements for the research, development, and testing of dress and protective clothing systems. GEO-CENTERS also determined cooperative opportunities for dual-use technology, technology transition, and technology exploitation.
- GEO-CENTERS prepared and delivered a technical briefing to highlight the technical expertise and unique facilities and equipment available at NCTRF.
- Delivered a complete set of colored vu-graphs, colored hard copies, 35mm slides, and disks which contained the briefing (94 vu-graphs). These disks will be used with a CPU to project the briefing through a video projector.

- Completed scanning 174 photos and delivered disks containing scanned material.
- Developed colored artist drawings of the Traversing Instrumented Manikin and the Hydro-Environmental Simulator.
- Developed and delivered a high quality reproducible color brochure, which outlined the NCTRF capabilities, product developments and specialized laboratories and equipment.
- Developed and delivered sample folder cover; obtained NCTRF comments and revised folder cover per recommendations.
- Revised draft brochure, folder cover, and information sheets in accordance with suggested changes obtained from NCTRF and produced a final product.
- Delivered electronic files for use in producing high quality brochures, folder covers, and information sheets.

Program IV: Great Lakes Prototype Footwear Test ***(Buller, Collins)***

- Provided technical support in the development of the Enhanced Chukka Shoe surveys for recruits, leaders, shipboard personnel and Naval Academy personnel.
- Provided technical support for experimental design of study.
- Provided software support in the production of an on-line data entry program and database management.
- Provided data collection support at the Recruit Training Center (RTC).
- Analyzed data by test group and prepared a final report of findings of the study.

Program V: Technical Reports ***(Schneider, Collins)***

- Analyzed and organized information provided on projects conducted in the Navy Clothing and Textile Research Facility (NCTRF).
- Developed technical reports and articles for publication in peer-reviewed journals.
- Work was completed on two technical reports for the Navy Clothing and Textile Research Facility (NCTRF) and bound copies of the final report were submitted to the Project Officer. The reports dealt with the development of rough sea simulation conditions in the NCTRF hydro-environmental tank. The first of the two reports, *Development of a Rough Sea Simulation Method for Testing Protective Clothing* was concerned primarily with the comparative effectiveness of eight different methods of water agitation in accelerating the heat loss from a thermal manikin positioned in the NCTRF hydro-environmental tank. The goal was to develop a method suitable for testing with human subjects which could replace the more expensive and hazardous ocean testing of immersion protection clothing systems. The second technical report, *Validation of Rough Sea Simulation Methods for Testing*

Protective Clothing: Comparison of Field and Laboratory Test of Body Cooling Rates, was concerned with the results of tests carried out with volunteers under ocean and laboratory conditions. The laboratory conditions were based on variations of a diffused compressed air method of water agitation in the NCTRF hydro-environmental tank. As part of the study a comparison was also made of the immersion protection performance of three clothing systems.

- The review of the draft copies of a third technical report, *Correlation of Thermal and Evaporative Resistances of Military Clothing Items, Measured on a Guarded Hot Plate and Thermal Manikin*, was completed by NCTRF and the changes and corrections requested by the Project Officer were incorporated in the document. In addition, changes were made in order to arrive at a more consistent designation of the various quantities used to describe thermal and evaporative heat transfer. Following the completion of these changes, it was decided to add figures illustrating the thermal manikin and guarded hot plate instrumentation, as well as the six clothing systems used in the study. The final draft of the report was submitted for editorial review and, after the indicated corrections were made, the report was printed and copies were delivered to the Project Officer.
- Work was completed on another report entitled *Comparison of Field and Laboratory Tests of Body Cooling Rates Using a Wave Maker to Simulate Rough Seas*. This report dealt with the development of a laboratory method of rough sea simulation for the immersion testing of protective clothing using a Wave Maker that was installed in the NCTRF environmental tank. Measurements were made of body cooling rates, both rectal and skin temperatures, as well as heat loss. Comparisons were made between the body cooling rates in successive wave maker trials and with the results of both calm water conditions and the body cooling rates experienced in earlier trials in the field at Cape May, NJ.
- A final report was completed as a Report of Invention (the first step in seeking a patent). The invention deals with a method of protecting the hands and other extremities from frostbite by extracting heat from warmer parts of the body and using a pumped fluid to transfer the heat to the chilled extremities. The use of the body as a source of heat and a pumped fluid for heat transfer overcomes the limitation of alternatives, such as a battery source of power for electrically-heated gloves or the use of heat pipes for body heat transfer. The full text of the report of invention has been developed with the title, *Pumped Fluid System for Body Heat Transfer.*

Program VI: Commercial Off-the-Shelf Utility Uniform Study (COTS) and The Utility Uniform Study (Buller)

Commercial Off-the-Shelf Utility Uniform Study (COTS)

- Designed questionnaire to assess fit, performance, durability and preference for two commercial off-the-shelf utility uniforms. The two styles are: 1) Redcap, and 2) Levi 505.

- Produced issue data sheets and explanatory package for subjects
- Reproduced questionnaires and issue packages.
- All data from the COTS study were analyzed using standard statistical techniques.
- All findings were integrated into a final technical report.

Main Utility Uniform Study

- Adapted questionnaire, data sheets, and explanatory package from subtask 1 for three uniform configurations: 1) 14 oz. Denim with 4 oz. Chambray Shirt, 2) 11 oz. Denim with 4 oz. Chambray Shirt, and 3) "Dickie" Style.
- Reproduced questionnaires and issued packages for all test participants.
- Provided support of two issuers to 16 test sites on the East and West Coasts, with approximately 75 test participants at each site.
- Provided support of two Human Factors Engineers to visit each test site twice during the duration of the study to issue and collect surveys and to collect subjects' comments. Visits occurred three and six months after issue of utility uniforms.
- Entered, cleaned, verified, and tabulated collected data.
- Analyzed data, based upon experimental design and study hypothesis, using standard univariate and multivariate statistical techniques.
- Prepared a final report detailing the whole study providing a clear explanation of the analytical techniques adopted and the conclusions reached from the analysis of the data.

Program VII: Oxford Shoe Study ***(Buller, Stern-Wolfson)***

- Designed questionnaire to assess fit, performance, durability and preference for three Oxford shoe sole configurations.
- Designed issue data sheets.
- Entered, cleaned, verified and tabulated collected data.
- Analyzed data based upon experimental design and study hypothesis, using standard univariate and multivariate statistical techniques.
- Prepared a final report detailing the study.

UNITED STATES NAVY
CERTIFICATION PROGRAM FOR
COMMERCIAL ENVIRONMENTAL/OCCUPATIONAL
PROTECTIVE CLOTHING/EQUIPMENT

U.S. Navy Clothing and Textile Research Facility
Protective Clothing Division
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GEO-CENTERS, INC.

GC-TR-96-2994-030

DRAFT REPORT

U.S. Navy
Certification Program for
Commercial, Environmental/Occupational (CEO)
Protective Clothing/Equipment

Prepared For:

U.S. Navy Clothing and Textile Research Facility
P.O. Box 59
Natick, MA 01760-0001
Under Contract No. N00014-95-D0048/003

Prepared By:

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JULY 1996

GEO-CENTERS, INC.

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GEO-CENTERS, INC.

U.S. Navy Certification Program for Commercial, Environmental/Occupational (CEO) Protective Clothing/Equipment

Objective

The objective of this program is to establish a process by which the Navy Clothing and Textile Research Facility (NCTRF) certifies, essentially commercial, off-the-shelf, protective clothing/equipment, with an acceptable performance history, as meeting or exceeding Navy standards. Commercial protective clothing/equipment items, certified through the procedures outlined in this document, which display a valid NCTRF certification number on a label attached to the item, may be purchased by Navy units or other Government procurement activities, directly from the certified product manufacturer. All provisions of this program apply equally to overseas manufacturers, as well as U.S. manufacturers.

Certification Process Outline

The first step in this process is to prepare a new Product Description which details the minimum salient characteristics (fit, form, and function) required from the commercial item to meet the minimum needs of the Navy. "Product Description" is a generic term for documents such as performance specifications, commercial standards, voluntary standards, commercial item descriptions or purchase descriptions, which are used for both high and low volume acquisitions. This Product Description will be prepared by the NCTRF and should initially be based on input from the Navy user community. It will be updated based on data obtained from the commercial marketplace. A market survey will then be performed using the Product Description to determine the potential for the commercial protective clothing/equipment to meet the Navy's essential requirements. Interested manufacturers will be required to submit a minimum of three sample production units of the protective clothing/equipment which they wish to have certified as meeting the new Product Description requirements. Specific details concerning the performance history of the item including any recall campaigns, will also be provided by the manufacturer. These production samples and all relevant data required herein must demonstrate that the item meets the

minimum performance needs of the Navy. Compliance with the Product Description will be validated by the NCTRF using appropriate test methods along with an assessment of the design compatibility, construction, quality, sizing systems, human factors, workmanship and durability. The design assessment can range from pure laboratory evaluation to limited field trials by appropriate Navy users, conducted on an accelerated basis. The results of these evaluations will be documented in a report.

Upon successful completion of the NCTRF evaluation, a Notice of Certification (see Appendix A-1) will be provided to the manufacturer. A distinctive tag (see Appendix A-2) will be attached to the item containing the certification number to indicate compliance with Navy protective clothing/equipment performance requirements. Acquisition of protective clothing/equipment that has a certification tag/number will assure shipboard personnel that they are receiving an item that meets all essential performance requirements, and is equivalent to or better than items purchased in accordance with a detailed military specification.

Protective Clothing/Equipment Items

The U.S. Navy Shipboard Protective Clothing Catalog, dated September 1994, published by the Naval Sea Systems Command (NAVSEA), lists more than seventy protective items divided into twelve functional tasks or environmental usage categories. The catalog is separated into a wide variety of clothing items ranging from utility clothing worn by most Navy shipboard personnel to highly specialized firefighter's protective clothing. This certification program covers all of the items listed in the above referenced catalog.

Identification of Protective Items

The protective clothing/equipment covered by this program can be divided into two broad categories of Personal Protection, as defined below. These categories are based on the risk to

survival and level of health hazard exposure that the users would be expected to encounter when performing his/her mission.

Category I <u>Environmental Protection</u>

A clothing item where user exposure to safety or health hazards is highly unlikely.

Category II <u>Critical Health Hazard Protection</u>

A more complex clothing item where significant potential exposure to serious safety or health hazards is expected.

Catalog Section	*Item/System Description*	*Personal Protection Category*
I	Utility Clothing and Accessories	I
II	Radioactive Contaminants Protective Clothing	II
III	Toxicological Agents Protective Clothing	II
IV	Anti-Flash Ensemble and Welding Gear	II
V	Chemical Warfare Protective Clothing	II
VI	Firefighter's Protective Clothing	II
VII	Wet-Weather Clothing (Ensemble)	I
VIII	Cold-Weather Clothing and Accessories	II
IX	Coveralls	I
X	Disposable Clothing	I
XI	Handwear	I
XII	Flight Deck Clothing	II

Certification Procedure for Category I Protective Items

The NCTRF will advise Navy users that a new Product Description is being developed. Users will be asked to provide pertinent operational/mission requirements in essential function or performance terms. NCTRF product engineers/technologists will assist users in accurately specifying requirements, as required. A complete market survey (research and analysis of information) will then be performed on the item to be certified using the Product Description to establish all essential requirements. Market survey sources are detailed in the Program Implementation section of this document (pg 8). Maximum effort will be made to identify as many competing available products as practical, and to describe the essential functional or performance characteristics to avoid dependance on a single source. Manufacturers will be requested to furnish the following data on their product:

- Item nomenclature/description, style number, manufacturing location and date of production initiation.
- Identification of at least three commercial users of the product and any military customer(s) including International Military Forces.
- Identification of commercial standards that are applicable to the item along with information demonstrating compliance with one or more commercial standards, such as those issued by the: National Fire Protection Association (NFPA), American National Standards Institute (ANSI), American Society for Testing and Materials (ASTM), Underwriters Laboratories Inc. (UL), etc.
- A short description of the government and commercial performance history of the item.
- A list and description of component materials used to produce the item.
- A report from an independent testing laboratory with sufficient data to determine compliance with requirements in the appropriate Product Description.
- Any proposed or planned changes or improvements to the item, identifying salient characteristics which would be improved.

- Description of commercial warranty available to the purchaser of the item.
- Information on proprietary aspects of the item, if applicable, including any patents which may have been issued.
- Information on any recall campaigns initiated either by the manufacturer or any Government agency.

The NCTRF will validate the performance and quality information provided by the manufacturer and compare performance capabilities with those required in the Product Description. This validation process will include both an assessment of data provided by the manufacturer, as well as the conduct of standardized tests by the NCTRF or another designated testing activity. While the NCTRF will have sole responsibility to determine the type and number of standardized tests to be conducted, all COE items submitted for evaluation will be subjected to identical testing without regard to the individual manufacturer. The NCTRF reserves the right to repeat tests performed for a manufacturer by independent test laboratories. Once these data are confirmed and the product has been determined to meet or exceed all essential Navy requirements, the manufacturer will be sent a Notice of Certification (see Appendix A-1). The quantity of samples to be provided for certification will be determined by the NCTRF on a case by case basis, and the manufacturer will be expected to provide up to ten certification samples at no cost to the Government. One of the original samples submitted for evaluation will be returned with the Notice of Certification. This sample will have a special identification and will be used by the manufacturer as the quality standard/guide for future production.

Certification Procedure for Category II Protective Items

The certification procedure for Category II items is the same as for the Category I items except that the NCTRF will conduct more extensive laboratory testing, some of which may be destructive. Limited user evaluations in a field setting will also be required. These field trials will frequently involve the use of significant quantities of the item being evaluated. The NCTRF will

purchase the quantities of items required for all field evaluations. Once available data are validated and the field evaluation is successfully completed, the manufacturer will be sent a Notice of Certification (see Appendix A-1). Also, one of the original samples submitted for evaluation will be returned with the Notice of Certification. This sample will have a special identification and will be used by the manufacturer as the quality standard/guide for future production.

Recertification of Category I and II Items

Category I and II protective clothing/equipment will be recertified at three-year and one- year intervals, respectively, or whenever the item is changed in any way. A change in product design, material, production process, product component, manufacturing location or component manufacturer will require recertification. The production samples and information required for recertification will be the same as for the original certification. Manufacturers should place special emphasis on describing in detail any technical changes (material change or design change) they have made or propose to make to the item since the last certification. The benefits to be derived from these functional improvements/changes should also be explained.

A product with a history of excellent performance and quality as illustrated through lack of warranty related actions, will not require the same in-depth evaluation during recertification as a product which has received one or more deficiency reports against the warranty. Excellent performance can be recognized and rewarded by a truncated recertification process. The NCTRF will determine which tests will be waived in recertifying an item with an excellent performance history.

Program Implementation

Navy protective clothing/equipment items, easily identified as having commercially similar products/applications, should be the starting point for this program. Utility clothing and accessories,

firefighter's clothing, wet-weather clothing and cold-weather clothing are items which are recommended for initial certification.

Market research and analysis will be conducted to identify readily available commercial products which potentially meet the functional needs of the Navy, and to identify candidates for certification under this program. Primary sources to establish current awareness of marketplace activities include, but are not limited to:

- Industry publications/catalogs and product data sheets.
- Federal Catalog System.
- General Services Administration (GSA) Catalogs.
- Trade shows and industry workshops.
- Journals and Symposia proceedings.
- Compilation guides and registers (e.g., Thomas Register).
- Automated databases (see DoD pamphlet SD-5, "Locating Off-the-Shelf Items").
- Defense Logistics Agency (DLA) Catalogs.
- Previous government contracts.
- Product deficiency and evaluation reports.
- Counterparts in other services, Federal or State agencies.
- Discussions with industry representatives.
- Visits to contractor facilities.
- Participation in standardization committees.
- Unsolicited proposals.
- Foreign military data exchange.
- International materiel evaluation.
- Patent searches.
- Government/Industry Data Exchange Programs.

Information gathered during the market survey should be analyzed to locate commercially similar products and identify those most compatible with essential Navy operational requirements. Also, any manufacturer having the potential capability to provide this product should be contacted to stimulate interest in the commercial sector. A "Sources Sought Notice" in the Commerce Business Daily (CBD) and selected trade publications could be used to develop interest and solicit additional manufacturers. Manufacturers should be encouraged or requested to submit production samples and product description data, along with relevant performance information/data.

All data should be evaluated to validate performance and results compared to the performance parameters of the product presently in the supply system. User assessment and approval will be necessary at this point if changes or improvements are significant, or could have a perceived impact on performance, reliability or durability. Logistical review/approval by the appropriate Navy supply element will be needed to address acquisition scheduling and logistical issues as well as supply catalog updates.

<u>Certification Policy</u>

The following policy should be established for the CEO certification program:

1) Notice of Certification should be provided for each successful product submission. If approved, a certification number will be assigned. Two of the samples will be retained by the NCTRF for historical records. Other samples and the signed/dated Notice of Certification with certification number, will be forwarded to the submitting manufacturer. These samples will be retained by the manufacturer as sample guides. Some samples may be destroyed during test and evaluation. Certification numbers are awarded to an individual firm for a specific item for its exclusive use and will not be used by any other company or for other items. Once an item is certified, it requires written approval from NCTRF for any deviation from the certified sample. However, every effort should be made to assist and

encourage manufacturers to improve certified item(s). A notice of deficiency should be sent to manufacturers of unsuccessful candidates, listing in detail the reason(s) for certification failure and the option to supply improved protective clothing/equipment samples for additional certification testing.

2) If a GSA Contract has been in effect for the purchase of an item of protective clothing/equipment equivalent to one used by the Navy, and the GSA can provide historical reliability and customer acceptance information, then the item could also be granted certification under this program. However, the NCTRF will determine if this information is sufficient or if additional testing is required on a case by case basis.

3) The Product Description will conform to the International Standardization Treaty Agreement, where applicable. Documents having potential NATO applications will be designed to support NATO Rationalization/Standardization and Interoperability.

4) The NCTRF has the option to make unannounced visits to manufacturers and/or certified manufacturer facilities to inspect and determine whether certified items being manufactured and sold to the Navy are equal to or better than the quality of the item for which certification was originally approved. For selected items, the NCTRF may purchase samples in the open market to validate quality and acceptable performance.

5) Color/shade control may require periodic/regular shade approval to achieve consistency in shade (item-by-item color uniformity). This would apply only when the items are intended to be worn during Military inspections, formations, drills, reviews or parades. When rigid shade control has been established as a necessary requirement, an acceptable color match to an approved shade standard will be required. All shade approvals will be made by the NCTRF under predefined and closely controlled lighting conditions. One 6 inch x 6 inch

swatch per stock-dyed or yarn-dyed lot will be required. Piece-dyed fabrics will require one swatch per piece (or roll) of fabric. The NCTRF will inform the manufacturer about the status of shade acceptance prior to fabrication of garments. Shade certified fabrics will have a decal printed on the back side of the fabric at 18-inch intervals across the width to illustrate that material is certified for proper shade. Current shade standards may be obtained from the NCTRF every six months or when appearance of the standards (surface soiled or nonuniform) makes valid shade evaluations questionable. Extreme care will be taken to prevent the use of inaccurate or altered shade standards in the dyeing of fabrics to a predefined shade.

6) A bulletin will be prepared and distributed to the NAVSEA, the Navy logistics and user community, informing them of the existence of a certification program for protective clothing/equipment item(s) along with a list of CEO items that can be purchased directly from commercial sources. In addition, NAVSEA will be notified of the certification number on the item label which indicates that the product they receive will have the same quality and functional performance level as the certified sample(s) on file at the NCTRF. This insures that the item meets or exceeds the appropriate and current Navy functional protective clothing/equipment standards. Customer comments (satisfaction, performance/functionality/ compatibility complaints) should also be solicited in this bulletin so that a performance history can be established, and any deficiencies corrected in a timely manner. A periodic bulletin will be prepared for the industry with information on new items to be submitted for certification, changes to item requirements and information on defective/substandard products which may have been sold to Navy customers under this program.

Revocation of Certification

Certification may be revoked at any time if it is determined that the certificate holder has violated any of the expressed conditions under which the certification was issued or for any of the problems listed below:

- Functional and/or durability deficiencies which demonstrate that the item is not equivalent in performance and quality to the certified sample.
- Workmanship/quality not at an acceptable level.
- Component materials or parts not the same or equivalent in performance and quality to the certified sample.
- Labeling requirements not as prescribed by the certification program.
- Failure to submit item for a quality check (recertification) within the prescribed time frame.
- Failure to permit inspection visit of manufacturing and warehousing facilities by NCTRF personnel.
- Failure to advise the NCTRF of any change in product material, design, construction or manufacturing facility.

Other Government Procurement Activities

Items which have been certified under this program may also be purchased by other Government procurement activities such as the Defense Logistics Agency, General Services Administration, U.S. Coast Guard, etc. The purchasing activity will identify the item using the nomenclature from the NCTRF CEO program, as well as the applicable Certification Number.

Warranties

All manufacturers who are certified under this program agree to warrant their items to be free from defects in materials, design and workmanship. This warranty has two components; shelf life

and service life. The shelf life period begins at the date of purchase and covers a maximum of 24 months. The service life begins once the item is issued to the user/service member and covers a maximum of 12 months. All warranty claims must be processed within 30 days from the date notification by the Government. Failure of the manufacturer to satisfactorily resolve any warranty claim may result in loss of certification.

APPENDIX

U.S. Navy Notice of Certification For Commercial Environmental/Occupational (CEO) Protective Clothing/Equipment

Certification No..............................

This certification for Category I ☐ or II ☐ protective clothing/equipment issued by the Department of the Navy, authorizes..to incorporate a tag, to include the above certification number, in all items produced which are equal to or better than the sample of...on which the issuance of this certification is based, so long as this certification is in effect.

By tagging a protective item with this Certification Number, the manufacturer is guaranteeing that the item is equal to or better than the functional/performance requirements contained in the approved Product Description, and also has been produced from the same materials, design, quality and workmanship exhibited by the sample under current certification.

Certification for Category I and II items are only valid for 3 years and 1 year, respectively, from the date of issue, at which time a new Notice of Certification will be required to continue participation in this program. It is the manufacturer's responsibility to submit a request for recertification in a timely manner.

Notice in writing, from the U.S. Navy Clothing and Textile Research Facility that this certification is revoked will negate the authority for use of this Certification and Certification Number.

In behalf of the Department of the Navy.. Date .... 19 ....

Officer in Charge

Sample
of
Certification Tag

Certification Tag	
Item Identification	Style/ Lot Number
"This item of protective clothing/equipment is warranted to meet or exceed the standards of Product Description _____________ and was produced under Certification No. _____________ from basic materials warranted by the manufacturer to have been produced in accordance with sample under current certification."	

Note 1: Supplier must provide on or near this label, a code to identify date (month/year) item was manufactured.

Note 2: Certification tag will be permanently located adjacent to the care label. This tag shall remain legible for the service life of the item or for as long as necessary to retain identity of certification number and production date.

GC-TR-96-2994-030

U.S. Navy Wear Test and User Evaluation of Commercial Safety Shoes

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Shipboard Study

Executive Summary

Results from a Navy Clothing and Textile Research Facility (NCTRF) survey of wearers of the *standard issue chukka shoe* indicated that both men and women have problems with fit and serviceability. As a result, NCTRF recommended that the standard Chukka shoe be replaced as soon as possible. A commercial market survey was undertaken and two commercial safety shoes were identified as being acceptable replacements. Each of these shoes came in two styles, one for men and one for women. This report details the user testing of these shoes.

The main purpose of the user test was not to compare the commercial shoes with the standard issue Chukka shoe, but to identify any potential medical, durability, and/or user acceptance problems with the male and female versions of each shoe. The candidate shoes were tested with three Navy populations: four divisions of new recruits at the Recruit Training Center (RTC), Recruit Division Commanders (RDC) at the RTC, and U.S. Navy personnel aboard three fleet ships.

RTC

At the RTC, 224 recruits participated in the test. Shoes were worn for a total of eight weeks, with each recruit receiving only one type of shoe. The recruits responded to three user surveys at the end of two, five, and eight weeks.

It was found that the commercial shoes were rated positively for almost all criteria, and were received favorably by the recruits. When comparing the two commercial shoes, very few differences were found. Most differences that were identified tended to be minor: for example, differences in ratings between "fair to good" and "good". The only major durability problem was the complete or partial separation of the heel from the shoe, which occurred with 23% of the recruits. Ventilation of the shoes was also a source of complaint, with 40% of recruits stating that their feet perspired and remained wet.

RDC

Originally, 72 RDC leaders were issued both pairs of commercial shoes, and wore each pair for three weeks. This study was aimed at comparing the two commercial shoe candidates. One user preference survey was completed for each of the candidate shoes. In addition, a comparison survey was administered after the RDCs had worn both pairs of shoes. No real differences were found between the two commercial candidates. Both shoes received positive ratings on all criteria. In addition, no durability problems were identified. However, the lack of ventilation was identified as a problem by about 30% of the wearers of both shoes.

Shipboard

Navy personnel aboard three ships were each issued one pair of commercial shoes. This component was designed to provide data from users in a shipboard setting. A total of 124 pairs of shoes were issued and were worn for eight weeks. A user preference survey, similar to the RTC and RDC surveys, was administered at the end of the test period. Again, no real differences were

identified between the two commercial shoes, and again, both shoes were rated positively on all criteria. Heel separation was the only durability problem occurring with 9% of the wearers. Ventilation was also a problem for approximately 24% of the wearers.

In conclusion, the wear test found that the commercial shoes from the Bates and the Craddock-Terry manufacturers performed well, and were generally liked by U.S. Navy personnel.

Acknowledgments

The Enhanced Chukka Shoe wear test was conducted at a number of Navy sites with the assistance of a large number of people. The following list acknowledges those who participated and helped with the organization of these studies.

1) Recruit Training Center; Great Lakes, IL.

CAPT	Whitehead
GMCM	Montgomery
DCCM	Reger
AMHC	Fordham
CEC	Guarnero
TMC	Penrod
AC1	Morin
MT1	Strayer
LCDR	Ward

All participating Divisions and Recruits and Division Commanders.

2) US Navy Ships

USS Gunston Hall;	DCC	Colwell
USS Shenandoah;	MC	De Lima
USS Deyo;	MC	Russell

All participating test subjects.

3) Navy Clothing and Textile Research Facility

Susan Reeps
Louise Caulfield
Alison Mack
Gilbert Alves
Bob Hall

4) Craddock-Terry, Inc.

Steve Selig
Eileen Paredes
Jack Kline
Tom Fitzgerald

5) Bates Shoe Company

Jim Reidy
Jim Schiffelbein
Roger MaGill
Dean Strand
Paige Unangst
Paul Lloyd

6) NEXCOM (u)

Becky Adkins
Rob Knapp
Jo Johnson

7) Naval Supply Systems Command

CAPT Easton

8) Battelle

Dr. Lisa Stern Wolfson

Introduction

The Chukka shoe has been a U.S. Navy item of standard issue for over 40 years. It is a black safety shoe, incorporating steel toe caps and nitrile rubber soles and heels. Prompted by unofficial reports of poor fit and discomfort, the Navy Clothing and Textile Research Facility (NCTRF) conducted a user survey in 1995. The survey found that both men and women had problems with: fit and serviceability; stiffness; weight; poor arch and ankle support; poor accommodation of women, and general discomfort. Survey respondents stated that they would like shoes with padded ankles, more arch support, better traction, and increased durability. Consequently, a commercial market survey (CMS) was conducted to identify a suitable shoe.

Two shoes were identified from the CMS, manufactured by two companies, *Bates* (Bates) and *Craddock-Terry* (CT). Bates and CT had originally produced their shoes to meet requirements for features such as steel toes, ankle support, nitrile rubber soles, water resistance, etc. Both companies produced their shoes in male and female styles.

The primary purpose of these studies was to identify any possible problem areas with the shoes and to confirm their suitability for Navy training and operational use. The goal was not to compare the shoes with each other, nor to downselect to one candidate, as both ECSs were identified by the Navy as meeting the requirements for Chukka shoes. The evaluation of the Enhanced Chukka Shoe (ECS) was conducted with three different Navy populations: recruits at the Recruit Training Center (RTC), Recruit Division Commanders (RDC) at the RTC, and sailors from three ships (USSs Deyo, Gunston Hall, and Shenandoah).

The largest component of the wear test was conducted at the RTC, using four divisions of recruits (two female divisions and two male). Two divisions, one female and one male, received the Bates shoe while the other two, received the CT shoe. Each recruit wore only one pair of shoes for the duration of their training.

The shipboard component, like the RTC, was concerned with identifying possible problem areas. Therefore, each participant received one pair of shoes for the entire wear period. Test participants onboard the USS Shenandoah were issued CT shoes, those onboard the USS Gunston Hall were primarily issued Bates ECS, while approximately half the sailors on the USS Deyo received the Bates shoes and the remainder CT.

The RDC study was designed to allow for a direct comparison of the Bates and CT shoes for both the male and female styles. The RDC participants were issued a pair of shoes from both companies and wore each for a continuous three-week period.

This report details the three components of the ECS wear test, examining the performance of the shoes in training and operational environments, and provides an assessment of the suitability of the shoes for the Navy as a whole.

Methodology

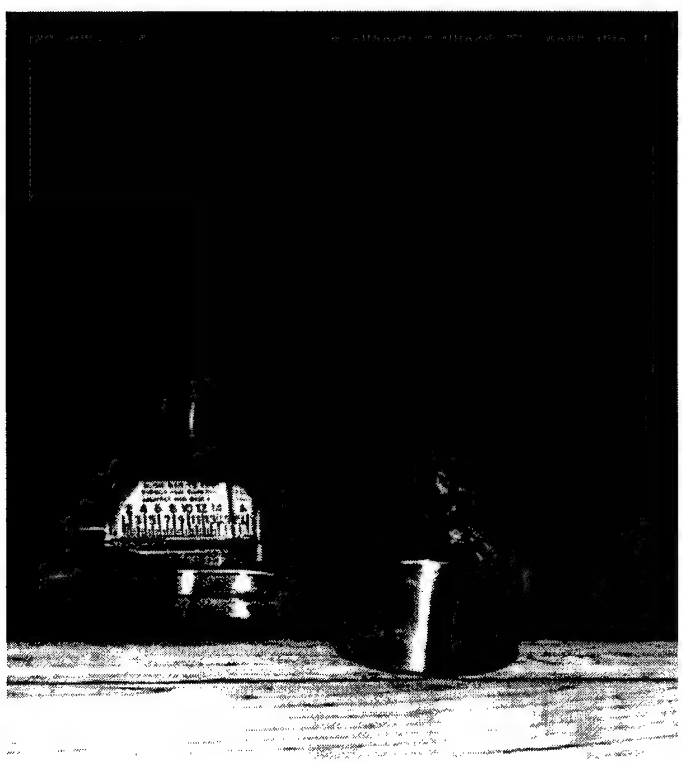
Experimental Design (General)

In all three studies, six major factors were measured: fit, wearers' ability to perform activities, comfort, medical problems, durability, and acceptability. All data were collected by questionnaire, and personal interview when appropriate. All studies used nearly identical surveys, with only minor modifications to account for the differences found between shore and sea duty, and the RDC study utilized an additional comparison survey. The RTC, RDC and shipboard preference surveys can be found in Appendices A, B, and C, respectively. The RDC comparison survey can be found in Appendix D.

Fitting of ECS

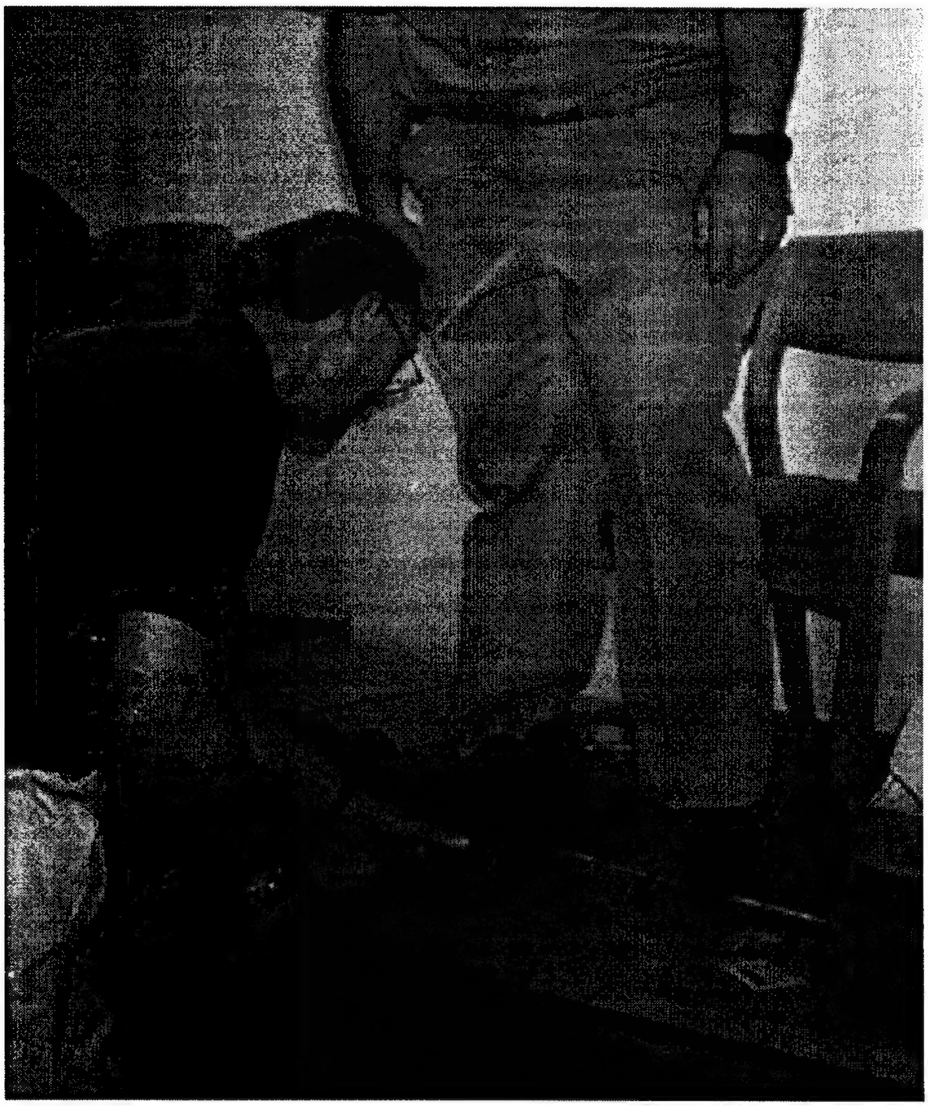
Test participants were sized by representatives from the two shoe manufacturers using the Brannock device to estimate the length and width size of both feet. Figure 1, shows a RTC recruit being sized using a Brannock device. This was a critical step of the evaluation, since an improper fit could adversely affect many factors such as: the performance of the individual, perceptions of comfort, acceptance, and even durability.

Figure 1: Sizing Using the Brannock Device



Individuals tried on a pair of ECSs based on their estimated shoe size as measured by the Brannock device. Participants donned the ECSs and the fit was evaluated by the shoe manufacturer's representative. If not satisfactory, additional sizes were tried until a proper fit could be attained. A test participant was not issued a pair of ECSs until the fit was acceptable to both the fitter and the recruit (See Figure 2). A demographic data sheet was completed for each participant, which listed the measured size, the issued size, and problems with users' feet or shoes. (See Appendix E)

Figure 2: Checking Fit of Shoe



Recruit Training Center - Recruit Study

Methodology

Subjects

Four companies of the RTC were identified to take part in this test: a male and female test group wearing the Bates shoe, and a male and female test group wearing the Craddock-Terry shoe. A total of 350 test shoes were issued initially to recruits at the RTC. Of this group, 224 recruits completed all three stages of the wear test, 116 in the Bates group and 108 in the Craddock-Terry group.

Design and Procedures

Each recruit received one pair of ECSs, either the Bates or the CT. Once sized and approved, individuals participated in regular recruit training. During this eight-week period, test participants were surveyed three times to elicit their feedback on the ECS. The surveys were administered at three intervals: two, five, and eight weeks.

At the three survey points, the test participants were divided into four groups, by shoe type and gender, and administered surveys. Test participants were then briefed on the purpose of the evaluation and the importance of their participation. During each questionnaire administration, the testers inspected any shoes with reported damage.

During the course of the eight-week test period, ECSs with defects or fit problems were turned in and documented with a questionnaire form (See Appendix F). ECSs were turned in only when the recruit deemed them unwearable.

In addition to the recruits' questionnaire data, supplemental data were obtained from RTC physicians who documented any foot problems which occurred during the test period. The purpose of collecting these data was to compare the number and severity of problems associated with the candidate shoes to the average number of problems associated with the standard Chukka shoe. The outcome of this inquiry will be discussed in the Results Section.

Results

a. Data Analysis

Data collected during surveys #1 through #3 of the study were summarized and analyzed using standard statistical procedures. For the experimental design, most variables, such as ratings over time, were analyzed using a standard repeated measures analysis of variance (ANOVA). The scaled data were analyzed with consideration to the following factors: shoe type, gender, ECS size, survey number (survey #1, survey #2, and survey #3), and interactions between these factors. Follow-up post hoc tests determined the factors that were statistically different. Results were deemed significant when the confidence level was equal to or greater than 95% ($p \leq 0.05$).

To further analyze significant differences identified by the ANOVAs, the ratings scale data of the two test shoes were compared using t-tests. The t-test compared the means received from the Bates and CT ECSs. When using the t-test to compare scores received from the three surveys, the 0.05 criterion level for individual t-tests was adjusted for "family-wise" error rate by utilizing the Bonferroni correction for multiple comparisons.

Also, tests of proportions on dichotomous data with consideration to gender, shoe size, and time duration were performed using the chi-square (χ^2) statistical test. Open-ended responses were tallied by shoe type and survey period. All scaled data were summarized in tables found in Appendix G. The data were summarized according to shoe type and survey number as no gender differences were detected for any of the test factors.

b. Demographics

The companies from the RTC that participated in this evaluation were randomly chosen. The average age of recruits was 20 years old, with the range between 18 and 28 years of age. The number of recruits participating in each survey is broken down in Table 1 by gender and ECS group.

Table 1: Recruit Participation by Survey

	Survey 1			Survey 2			Survey 3		
Gender	**M**	**F**	**Total**	**M**	**F**	**Total**	**M**	**F**	**Total**
Bates	73	55	**128**	72	49	**121**	67	49	**116**
CT	56	52	**108**	67	42	**109**	68	48	**116**

M=male recruits; F=female recruits

The variation in the number of recruits participating in each survey is a result of dropouts from the program, and the unavailability of recruits during survey times. In addition, some test participants turned in their boots due to damage that occurred between the second and third surveys, and therefore, did not complete the test.

Of the total test group, 97% wore their ECSs every day for over 10 hours a day. The remaining 2% of the recruits from the Bates group and 1% of the recruits from the CT group substituted sneakers briefly during the test due to foot and leg problems. These medical problems were unrelated to either ECS.

The vast majority of participants wore two pairs of socks with their ECSs: one pair of white athletic socks, and one pair of black issue socks. Many individuals stated they wore this sock combination because it was mandatory for recruits, while others stated that the combination offered comfort and prevented blisters.

The practice of adding inserts increased for both types of shoes over the course of this test, with the majority of the recruits reporting the use of Dr.Scholl's insoles and Odor Eaters. Overall, the increase in insert usage rose from 20% of the recruits in survey #1 to 38% by survey #3. Significantly more inserts were added to Bates shoes during the first weeks of the evaluation than were added to the CT shoes (χ^2=13.96, df=1, p<.001). By the third survey, the CT shoe wearers had increased their insert usage, and were equal to the Bates wearers. It is interesting to note that while the Bates wearers steadily increased their use of inserts, the number of CT wearers who added inserts remained low for surveys #1 and #2 but quadrupled by survey #3.

It is unclear why the Bates wearers added inserts sooner than the CT wearers, especially when considering that by the eighth week both groups were equal in insert usage. However, it is common practice for company commanders to advise recruits to add inserts to their issue shoes. While it is unclear how many of the RTC group were advised to add inserts, this practice may account for the insert usage by the Bates and CT wearers. Table 2 below demonstrates the increases within each ECS type.

Table 2: Number of Inserts Used by Survey

	Bates	CT
Survey #1	36 (29%)	10 (09%)
Survey #2	40 (33%)	10 (09%)
Survey #3	50 (43%)	38 (43%)

Of those adding inserts to their ECSs, three reasons were offered by users of both candidates. Individuals most often added inserts to increase the comfort, cushioning, and arch support of their shoes. As demonstrated in Table 3, a greater proportion of the Bates group than the CT group reported experiencing problems with their shoes, which lead them to purchase inserts.

Table 3: Reasons for Additional Inserts

	Bates N=36 (28%)	CT N=16 (15%)
Additional Cushioning	11	3
Additional Comfort	7	6
Additional Arch Support	3	2

c. Fit Assessment

Eight factors were measured to assess the fit of the shoe: ease of donning, ease of doffing, fit of ankle, fit of toes, fit of heel, fit of instep, arch support, and ankle support. When looking at the consistency of responses for fit criteria across the three surveys, very few differences were detected. There was one difference found with the CT shoe with respect to fit. The ability to don the CT shoe was rated significantly easier during the first test period than it was during survey #2 ($F=5.19$, $df=2, 122$, $p<.007$). It should be noted that responses received from all three surveys for the CT shoes fell in the "easy" to "fairly easy" categories.

When comparing the Bates and the CT shoes within each test period on fit criteria, consistent differences between the two ECSs were detected. For all three surveys, the Bates shoe was rated significantly easier to don than the CT shoe ($t=-4.73$, $df=213$, $p<.001$; $t=-7.33$, $df=220$, $p<.001$; $t=-6.55$, $df=213$, $p<.001$, respectively). Seventy-nine percent (n=85) of the CT group experienced a problem donning the ECS, compared to the 32% (n=37) of the Bates group. Respondents were asked to explain the problems they had donning their ECSs. Breaking down the responses by ECS candidate, Table 4 provides the total number of complaints, and the most common complaints for each shoe.

Table 4: Donning Complaints by Shoe

	Bates N=116	CT N=108
TOTAL NUMBER OF PROBLEMS	37 (32%)	85 (79%)
Unlace to don	13 (11%)	27 (25%)
Heel/Ankle tight	8 (7%)	18 (17%)
Tongue/Instep tight	2 (2%)	17 (16%)

Similar results were obtained for doffing the ECS candidates, where the Bates shoe was rated as significantly easier to doff than the CT shoe for all three surveys ($t=-3.86$, $df=211$, $p<.001$; $t=-5.97$, $df=219$, $p<.001$; $t=-5.16$, $df=213$, $p<.001$, respectively). The Bates shoe was consistently rated as "easy", where the CT shoe was rated as "fairly easy" for doffing. Table 5 lists the total number of complaints for each ECS and the top three complaints for each shoe. The table shows that 41% (n=44) of the CT group experienced a problem doffing the ECS, compared to 16% (n=18) of the Bates group.

Table 5: Doffing Complaints by Shoe

	Bates N=116	CT N=108
TOTAL NUMBER OF PROBLEMS	18 (16%)	44 (41%)
Unlace to doff	11 (9%)	19 (18%)
Heel/Ankle tight	3 (3%)	10 (9%)
Tongue/Instep tight	1 (<1%)	4 (4%)

No differences were identified between the two shoes when rating the fit of specific areas of the foot. The fit of the ankle, toes, heel, and instep was rated as "just right" by the Bates and CT wearers. The same rating was received by both groups of ECS wearers when evaluating the overall fit. The shoes were also rated equally for ankle support, with both shoes receiving a "good" rating. However, the ECS candidates were both rated as "fair" for arch support on all surveys.

d. Ability to Perform Activities

The performance of the test shoes was measured by the users' ability to walk, run, march, and stand. An interesting trend appeared in users' ratings of standing and marching in the two ECS candidates. The ratings received from Bates wearers for these two activities demonstrated an increase in performance over time, while the CT wearers' ratings of performance decreased over time.

The ratings received for standing in the Bates shoe rose significantly between survey #1 and survey #3 ($F=4.11$, $df=2,116$, $p<.02$) from "fair" to "good". Again, this could be the result of the increase in insert usage in the Bates group. The Bates group's ratings for walking, running, and marching were positive and consistent during the evaluation. Conversely, the CT ECSs ratings for users' ability to run, significantly decreased between survey #1 and survey #2 ($F=3.60$, $df=2, 114$, $p=.03$), and decreased for marching between surveys #1 and #3 ($F=4.33$, $df=2,188$ $p<.02$). The ability to walk while wearing the CT shoes was consistently positive for the three surveys.

Similarly, when comparing the two ECS candidates within each survey period, there were no differences in the ratings received for the two ECSs for ability to walk, run, or march. For ability to stand, the Bates shoe received a significantly higher rating compared to the CT shoe ($t=2.74$, $df=213$, $p=.007$; $t=4.84$, $df=220$, $p<.001$; $t=4.86$, $df=213$, $p<.001$). The CT shoe was rated as "fair" for standing in throughout the test, while the Bates shoe increased from "fair" in survey #1 to "good" in surveys #2 and #3. Table 6 below illustrates the ratings received for the performance criteria.

Table 6: Average Ratings of Recruits' Ability to Function

	BATES SHOE			CT SHOE		
	Survey #1	**Survey #2**	**Survey #3**	**Survey #1**	**Survey #2**	**Survey #3**
Ability to Stand	**2.46**	**2.64**	**2.68**	**2.23**	**2.27**	**2.27**
Ability to Walk	**2.69**	**2.79**	**2.81**	**2.85**	**2.78**	**2.75**
Ability to Run	**2.19**	**2.25**	**2.29**	**2.33**	**2.06**	**2.12**
Ability to March	**2.60**	**2.73**	**2.75**	**2.82**	**2.77**	**2.62**

Rating Scale: 1.00=POOR 2.00=FAIR 3.00=GOOD

The traction of each candidate ECS on a variety of surfaces was also investigated during this evaluation. No differences were found between the two shoe types, and all ratings indicate no problems traversing any of the surfaces, as Table 7 demonstrates.

Table 7: Traction Ratings for Common Surfaces

	Bates	CT
Wet/Moist	2.80	2.67
Oil Covered	3.40	3.46
Waxed	2.67	2.81
Nonskid	2.98	3.09
Painted	3.24	3.27
Grass	3.21	3.38
Mud	3.15	3.12
Pavement	2.92	2.90
Carpet	3.37	3.40
Wooden Surface Floors	3.28	3.31

1.00=Poor, 2.00=Fair, 3.00=Good

e. Comfort

Test participants were asked to rate the comfort of the shoes on three factors: break-in period, ability of shoes to keep feet dry, and thermal comfort. The most prominent factor when measuring the comfort of the ECSs is the break-in period. There was little difference in the time necessary to break in the ECSs. Both groups reported wearing the ECSs an average of six times before they were broken in. There were a large number of individuals from each of the shoe groups who did not feel the ECSs needed to be broken in at all, 31% from the Bates group (N=40) and 25% from the CT group (N=27). Few individuals felt that the ECSs could not be broken in at all; 3% of the Bates group (N=4), and 6% of the CT group (N=6).

The majority of the ECSs became wet (N=154, 66%) during ordinary RTC training. When this occurred, 96% of the ECSs kept the wearers' feet dry. Again, there were no differences between the water resistance of the two candidate ECS. The drying time of the ECSs was also equal in both groups. Users reported that the shoes dried completely in one to three hours. The only method used for drying the ECSs was air-drying. In addition, users' ratings of the thermal comfort of the two candidate shoes were equal, with the Bates and CT shoes both rated as "just right" on all three surveys. However, perspiration from wearing the ECSs caused nearly half the group to respond that their feet stayed wet (N=107, 48%). This ventilation problem occurred equally within each ECS type.

f. Medical Problems

A list of common foot problems associated with footwear was provided to test participants who indicated which ones, if any, they had experienced. Table 8 details these foot problems. Statistical tests determined that there were no differences in the incidence of foot problems between the ECS types.

Table 8: Reported Foot Problems Associated with ECS

	Bates n=219	CT n=242
Foot Problems Experienced:		
Blisters	45% (53)	46% (54)
Aching feet	42% (49)	50% (58)
Callouses	41% (48)	38% (44)
Foot cramps	21% (24)	26% (30)
Aching legs	21% (24)	26% (30)
Aching back	11% (13)	12% (14)
Other	7% (8)	10% (12)

In addition to this data received from the recruits, supplemental data were received from medical personnel. A breakdown by ECSs and type of foot problem of individuals who received medical attention is located in Appendix H. A memorandum was also furnished by medical personnel discussing the rate of problems associated with the standard Chukka versus the incidence of foot problems associated with the prototype ECSs. The podiatrists concluded that the test boots are superior to the standard Chukka shoe in construction and design, and reported no increase in the incidence of foot problems experienced by the recruits. This memorandum can be found in Appendix I.

g. Durability

Approximately 81% of the group (N=182) reported some type of damage to their ECSs; 105 recruits from the Bates group and 77 from the CT group. The severity of the damage ranged from eyelet paint chipping off to heels separating from the ECSs. The damage reported from each shoe group is listed in Table 9 along with the number of individuals experiencing the problem.

Table 9: Reports of Damage for Both ECS Candidates

	Bates n=105	CT n=77
Type of durability problem:	**n**	**n**
Heel separating	9	2
Heel came off	8	8
Unspecified heel problem	10	4
Scuff/tear toe area	20	18
Eyelet paint wearing off	58	45

As Table 9 demonstrates, the most common durability problems associated with the ECSs were the peeling of the eyelet paint and the scuffing and/or tearing of leather in the toe area. When shoe damage was analyzed by size, it was equally spread across all sizes for both of the shoe candidates. This demonstrates that no one particular shoe size differed from the others in its construction and durability. Also, when comparing the damage reports between males and females, the female damage reports were proportional to the number of females who participated in each ECS group. In summary, there were no ECS group differences or gender differences on the reported damage to the shoes.

Despite the reports of damage listed above, few ECSs were actually turned in. Damaged ECSs were replaced only during the first three weeks of the evaluation. After this time, individuals were requested to turn in damaged ECSs for inspection at the next survey, and their standard Chukka shoes were reissued to them. According to the Defect Sheets (See Appendix F) collected, three CT ECSs were turned in, and seven Bates ECSs were turned in due to heels separating completely from the shoes. However, the recruits indicated that eight pairs of each ECSs experienced this problem. It is assumed from feedback received from the recruits, that after the initial turn-in and replace-time frame, individuals held onto their ECSs despite the damage rather than return to the standard Chukka shoe. This means that many individuals continued to wear ECSs with separating heels, and a couple of individuals wore ECSs without heels rather than turn in the shoes.

h. Acceptability

Test participants were asked to rate the appearance of the ECS candidates. Both ECSs were rated positively for appearance on a five-point scale (1=really dislike, 3=fair, and 5=really like). The "overall rating" of the Bates shoe was significantly higher than that of the CT shoe for

the second survey, 4.1 and 3.7 ($t=4.14$, $df=216$, $p<.001$), yet equal to the CT shoe in surveys #1 and #3. The CT ECS received its highest ratings for this criterion in the first survey, and then its ratings decreased slightly in surveys #2 and #3.

In order to get a measure of the acceptability of the ECSs, participants were asked if they would continue to wear the ECSs once they left the RTC. Eighty-four percent (N=183) of the total group do plan to wear the ECSs after leaving the RTC. Both the Bates shoe and the CT shoe responses were equal for this inquiry.

In order to determine the features of the ECSs that were most favorable to respondents, recruits were asked to list the features of the ECSs that they liked and disliked. When these features were tallied for each of the boots there were some interesting differences. The CT shoe received more responses on specific features, while the Bates shoe received more responses indicating an overall preference for the total shoe. Tables 10 and 11 list the features of each shoe most commonly liked and disliked, respectively.

Table 10: Most Commonly LIKED Features of the ECS:

	Bates	CT
Roll cuff	31	46
Tongue	11	21
Sole	10	14
Ankle support	9	7
Leather	5	4
Entire shoe	24	6

Table 11: Most Commonly DISLIKED Features of the ECS:

	Bates	CT
Sole	6	17
Tongue	4	10
Roll cuff	4	1
Heel	5	6
Lack of cushioning	3	4

Discussion

The RTC provided a structured environment for testing the candidate shoes. The four divisions which tested the Bates and the Craddock-Terry shoes were comprised of recruits undergoing the same training. The RTC training environment allowed the candidate shoes to be evaluated by individuals based on equal wear time, usage, and training procedures.

Overall, both the Bates and the CT ECSs performed well and were received favorably by recruits at the RTC. The data analyses demonstrated no gender differences in the results received for all factors of this evaluation. Males and females were equal in their ratings of all test criteria.

For all fit and acceptability criteria, with the exception of arch support, the ECSs were rated positively by the recruits as well as medical personnel. The arch support offered by both ECSs was rated as "fair". Comparatively, the CT shoe was more difficult to don and doff compared to the Bates shoe as a result of the narrower instep. Because of the increased difficulty with these tasks, CT wearers often unlaced their shoes to get them on and off. All other ratings on fit criteria, including the ankle support, break-in time, and insert usage, were equal for both shoes. Interestingly, the Bates wearers purchased commercial inserts early in the evaluation than did the CT wearers. However, by the third survey period, the CT group was equal in its usage of inserts. Traction problems and the reports of damage were also equal for both candidates.

Results of performance criteria demonstrated that the ability of wearers to walk, stand, and march in the candidate shoes were positive across all three surveys. The ratings received for running tended to be lower than the other performance criteria for both shoes, with results falling in the "fair" category. Only one significant difference was detected between the candidate shoes on the performance criteria. The Bates shoe was rated significantly better for standing than was the CT. These ratings could have been affected by the widespread use of inserts by the Bates group early in the evaluation.

Ventilation of the ECSs to alleviate sweat was a common comfort issue for both ECS candidates. Over 40% of both groups experienced consistent sweating and wetness of feet. This is most likely a trade-off between this type of footwear, which is constructed to provide safety and durability, and mild user discomfort caused by sweating.

A major consideration of this evaluation was to measure the incidences of foot problems for both ECSs. The reported problems received by the recruits decreased over time between the first, second, and third surveys. Both candidates were deemed acceptable by users, and good candidates for the replacement of the standard Chukka shoe.

Overall, there were few differences between the two candidates, and those that occurred were minor. In fact, medical personnel from the RTC reported that the candidate shoes were superior to the current Chukka shoe worn by recruits. Medical personnel also reported no increase in the incidence of foot problems with the shoes when compared to the standard Chukka shoe.

Recruit Division Commanders' Study

Methodology

Subjects

A total of 72 (49 Male, 23 Female) RDCs participated in this study. However, surveys were returned by only 57 (39 Male, 18 Females). Of the returned surveys, 40 subjects had completed a preference survey for both pairs of shoes (26 Male, 14 Female). Since this evaluation was designed to compare the two shoe types, only the data from the 40 subjects who completed a questionnaire for both pairs of shoes were retained for analysis.

Design and Procedures

To obtain a direct comparison of the ECSs, with a limited number of subjects, each participant was issued a pair of Bates shoes, and a pair of CT shoes. The test period lasted six weeks, with each shoe being worn for a continuous three-week period. This allowed sufficient time for break-in, and user accommodation to shoe characteristics. The possible effect of shoe order on preference was controlled by randomly assigning either Bates or CT shoes to be worn first. Thus, approximately 50% wore Bates shoes and 50% wore CT shoes in the initial three weeks. Users then wore their second pair of shoes for the remaining three weeks. The ECSs were worn in place of the subject's regular military shoe.

Preference questionnaires were completed after each three-week wear period. A total of two preference surveys were completed by each subject, one for each type of shoe. Direct comparison data of the shoes were further obtained by a comparison questionnaire, administered at the end of the six-week wear period. This questionnaire addressed all six areas of investigation, and asked users to select their preferred shoe. A copy of the comparison survey can be found in Appendix D.

Results

a. Data Analysis

Data from the preference questionnaires were summarized, and means and standard deviations were calculated. Open-ended questions were analyzed and common responses tallied. Frequencies of responses to the RDC comparison survey were computed. The data were analyzed using two standard statistical procedures. The Pearson Chi Squared (χ^2) statistic was applied to dichotomous data, while a two factor, split-plot Analysis of Variance (ANOVA) was used in the analysis of scale and continuous data. Shoe type (Bates vs CT) served as the with-in subject factor, and gender was a between-subject factor. Results were deemed significant when the confidence level was equal to or greater than 95% ($P \leq 0.05$).

b. Demographics

In order to fairly compare the Bates and CT shoes, it was important to have subjects whose shoes fit correctly. Using the overall fit rating in the preference questionnaire, those subjects who rated the overall fit of both the Bates and CT ECSs as "just right" were identified. Only their data were included in the analysis. Of the original 40 subjects considered for the analysis 73% were fit well for both ECSs (22 Male, 7 Female). Table 12, shows the overall fit ratings by shoe type and gender. (Note: "Bad" fit ratings are not necessarily from the same subjects)

Table 12: Ratings of Overall Fit

	Bates		CT	
	M	F	M	F
Good	24	11	24	10
Poor	2	2	2	2

(Good="Just Right" Poor="Too Loose" OR "Too Tight")

c. Fit Assessment

Table 13 shows the reported frequency with which test participants wore the shoes. Approximately half the subjects wore both shoes every day. The approximate average wear time for shoes was between 7 and 9 hours, and was the same for males and females, and shoe type. Inserts were rarely utilized, with only four participants reporting the use of them.

Table 13: Wear Pattern

	Bates		CT	
	M	F	M	F
Wear Every Day	11	3	9	3
Do Not Wear Every Day	11	4	13	3

Eight factors were used to assess the fit of the shoes: ease of donning, ease of doffing, fit of ankle, fit of toes, fit of heel, fit of instep, arch support, and ankle support. All fit factors were rated positively, and the split-plot ANOVA revealed no significant differences in ratings between the ECSs or by gender.

d. Ability to Perform Activities

Wearers' ability to perform various activities was measured by ratings of: ability to stand, walk, run, and march. Table 14 shows the mean rating for each measure. All ratings were better than "fair", with the vast majority of measures receiving a rating of close to "good". An ANOVA revealed no significant differences between mean responses for either shoe regardless of gender.

Table 14: Mean Ratings of Factors Assessing Wearers' Ability to Function

	Bates		CT	
	M	F	M	F
Ability to Stand	2.91	2.86	2.91	3.00
Ability to Walk	2.82	2.71	2.77	2.57
Ability to Run	2.57	2.33	2.50	3.00
Ability to March	2.79	2.33	2.64	2.67

1.00=Poor, 2.00=Fair, 3.00=Good

Shoe performance was further characterized by rating each shoe's traction on a number of surfaces. Table 15 presents the mean ratings for traction on a number of different surfaces.

Table 15: Traction Ratings for Different Surfaces

	Bates		CT	
	M	**F**	**M**	**F**
Wet/Moist	2.90	2.93	2.95	3.00
Oil Covered	3.00	2.67	3.00	3.00
Waxed	2.81	2.83	2.95	3.00
Nonskid	2.92	2.83	3.00	3.00
Painted	2.89	2.80	3.00	3.00
Grass	3.00	2.80	2.88	3.00
Mud	2.93	2.75	2.86	3.00
Pavement	2.95	2.86	3.00	3.00
Carpet	3.00	2.86	3.00	3.00
Wooden Surface Floors	3.00	2.75	2.93	3.00

1.00=Poor, 2.00=Fair, 3.00=Good

Both the Bates and CT shoes provide good traction on all surfaces. All surfaces rated received a mean traction rating close to "good". No significant differences were found between the mean traction ratings for either shoe on any surface. This held true for males and females.

e. Comfort

Comfort was measured in three different ways: break-in period, ability of shoes to keep feet dry, and thermal comfort. The reported break-in times for both ECSs were very short, with mean break-in times from 2.24 to 4.83 days. An ANOVA revealed no significant differences between ECSs, regardless of gender.

Both shoes were found to keep wearers' feet dry. Approximately 30% of Bates and CT shoes became wet. All subjects whose shoes became wet, found that the ECSs adequately kept their feet dry.

The mean thermal comfort rating of the Bates and CT shoes was close to "just right" for each shoe (Bates & CT 1.86, scale: 1=Too Warm, 2= Just Right, 3=Too Cold). An ANOVA found no significant differences between the ratings of either shoe regardless of gender. Although the mean rating is close to "just right", some test participants found that both shoes had a tendency to retain moisture and did not "breathe". Thirty-one percent of Bates wearers and 27% of CT wearers said that their feet had perspired and remained wet.

f. Medical Problems

The number of shoe wearers reporting medical problems is displayed in Table 16, along with the tally of each medical problem reported. In detailing the type of medical problem experienced, each subject was able to check all problems that occurred.

Table 16: Medical Problems Experienced

	Bates	CT
Medical Problems	31% (n=9)	21% (n=6)
Blisters	-	1
Foot Cramps	-	1
Aching Legs	-	-
Callouses	-	-
Aching Feet	5	3
Aching Back	-	-
Other	4	1

Note: Other includes: Tender/Aching Toes, Sore/Rubbed Ankle, Tender Heels, and Unspecified problems.

Although a number of medical problems were reported, none of these required medical attention and most problems reportedly went away after the break-in period.

g. Durability

No durability problems were identified during the RDC study. Even when subjects whose shoes did not fit well were included in the analysis; no problems were identified.

h. Acceptability

Acceptability of the ECSs was measured in a number of ways. Ratings were obtained for style, and overall satisfaction and performance. Test participants were also asked if they would purchase the ECS themselves. In addition, open-ended questions asked users to list their most and least favored features.

The style and overall ratings are presented in Table 17.

Table 17: Mean Style and Overall Ratings

	Bates		CT	
	M	F	M	F
Style	4.23	4.43	4.33	3.71
Scale: (1=Really Dislike, 3=Fair, 5=Really Like)				
Overall Rating	4.14	4.42	4.22	3.42
Scale: (1=Very Poor, 3=Fair, 5=Excellent)				

Both shoes were rated similarly for style, with ratings close to "like". An ANOVA found no significant differences between the shoe styles regardless of gender. The overall ratings were all slightly better than "good", except for the female rating of the CT shoe, which was close to "fair". The lower overall female rating of the CT shoe is significantly different than that of the Bates ($F=4.59$, $df=1,27$, $p=0.041$).

Table 18 shows the number of test participants who would or would not buy the ECSs which they had worn.

Table 18: Purchase of Enhanced Chukka Shoes

	Bates		CT	
	M	F	M	F
Would Purchase	21	7	21	4
Would Not Purchase	1	0	1	3

The purchase response of the females for the CT shoe was significantly different from the responses of the males for the CT shoe and the responses for the Bates shoe (χ^2=6.55, df=1, p=0.01). This was consistent with the pattern in the overall mean ratings for shoes.

Table 19 shows that the roll cuff on the ankle support is the most liked feature for the Bates shoe (n=9) and second most liked for the CT shoe (n=5). The most favored feature of the CT shoe is the padded tongue (n=11).

In contrast, Table 20 shows that the most disliked feature of the Bates shoe was the unpadded tongue. All other disliked features for both shoes were only reported once.

Table 19: Most LIKED Features

	Bates	CT
Roll Cuff/Ankle Cushion	9	5
Ankle Support	2	-
Tongue	1	11
Sole	1	-
Inserts	2	-
Leather	-	1
Heel	1	-
Arch fit	1	1

Table 20: Most DISLIKED Features

	Bates	CT
Tongue	6	-
Sole/Hard	1	1
Laces/Lace Holes	-	1
Steel Toe	1	1
Roll Cuff	-	1
Weight	1	1
Insole	1	-
Heel	-	1
Need Cushioning	-	1

i. RDC Comparison Survey

The responses from the comparison survey were tallied. The percentages of subject responses for each question are displayed in Table 21. Wearers were asked to choose which shoe they preferred for a number of parameters: fit, ability to function, comfort, and shoe performance. A large proportion of respondents selected both shoes as equal in most categories. When subjects expressed a preference for one shoe over the other the Bates shoes received more favorable responses than the CT shoes for all factors except users' ability to run, for which the CT shoe received more favorable responses.

Table 21: Comparison of Shoes for Various Characteristics

	Bates (%)	CT (%)	Same (%)
Overall Shoe Preference	42.1	36.8	21.1
Fit	44.7	28.9	26.3
Comfort	42.1	36.8	21.1
Durability	18.4	13.2	68.4
Traction	21.1	13.2	65.8
Thermal Comfort	31.6	21.1	47.4
Water Repellency	21.1	15.8	63.2
Standing	34.2	26.3	39.5
Walking	44.7	34.2	21.1
Running	31.4	34.3	34.3
Marching	40.0	31.4	28.6
Comfort of Ankle	36.8	26.3	36.8
Comfort of Toes	34.2	31.6	34.2
Comfort of Heel	31.6	28.9	39.5
Comfort of Instep	47.4	21.1	31.6
Fit of Ankle	31.6	28.9	39.5
Fit of Toes	39.5	28.9	31.6
Fit of Heel	34.2	26.3	39.5
Fit of Instep	39.5	26.3	34.2
Easier to Break In	39.5	15.8	44.7
Easier to Put On	37.8	10.8	51.4
Easier to Take Off	35.1	8.1	56.8

(Percentages may not add up to 100% due to rounding)

Discussion

The RDC wear test was aimed at identifying any major problems experienced with the Bates and CT shoes. This was done by subjecting them to direct comparison in a training setting. The results of the preference survey indicated that both shoes were acceptable to the user. Both shoes were rated positively for fit, users' ability to run, walk, march and walk, traction over different surfaces, appearance, and overall rating. Break-in times were short, between two and five days and the thermal comfort of the shoes was found to be "just right" and kept the wearers' feet dry.

Although, both ECSs in a number of cases caused minimal medical problems, such as blisters, these problems were not found to be lasting, generally being cleared up after the shoes were broken-in. No subject needed professional medical treatment for these ailments.

The only area in which comfort was affected in a negative way was in the breathability of the shoes. Thirty-one percent of Bates and 27% of CT wearers said their feet had perspired and remained wet.

In the preference survey (performance and user acceptability), there were no differences found between the Bates and CT shoes. On almost all factors of comparison no statistical differences were found. With respect to acceptability, the female overall rating of the CT shoe was significantly lower than that of the Bates. This is a difference of "fair" to "good". This finding was further confirmed by the response of almost 50% of the females who stated that they would not buy the CT shoe, but did state that they would buy the Bates shoe. It should be borne in mind that this was the response of only three female subjects. While these differences are real, the "fair" rating of the CT shoe is not negative. One of the respondents said that if given the choice between the current Chukka shoe and the CT shoe, she would purchase the CT shoe. These two results may indicate a slight preference for the Bates shoe in a female population. In comparing the most liked and most disliked aspects of both shoes one characteristic stands clear. The padded tongue of the CT shoe is the most liked feature, while the unpadded tongue of the Bates shoe is the most disliked feature. This result makes the suggestion that a padded tongue should be adopted by all ECS manufacturers.

The comparison survey found that the Bates shoe was favored more than the CT shoe on all characteristics except one. The mean female ratings and purchase responses indicated a slight preference for the Bates shoe, but no other trend in the preference data was found.

In conclusion, this study found that the Bates and CT shoes are good replacements for the present Chukka shoe. Both shoes were rated positively and were found to be acceptable by the test participants.

Shipboard Study

Methodology

Subjects

One hundred and twenty-four subjects were issued shoes (74 Males, 50 Females). Table 22 lists the shoes issued to each ship.

Table 22: Shoes Issued by Ship

	Bates		CT	
	Male	**Female**	**Male**	**Female**
Deyo	10	-	15	-
Shenandoah	-	-	25	26
Gunston Hall	23	22	1	2

Of the 124 original test participants, 95 (58 Male, 37 Female) returned completed questionnaires. Of these, 44 surveys were for the Bates shoe (28 Male, 16 Female) and 51 for the CT shoe (30 Male, 21 Female).

Design and Procedures

The purpose of the shipboard wear test was to identify any major problems with ECSs in an operational setting. Toward this end, a between-subjects design was adopted and each subject received one pair of shoes, either a pair of Bates or CT. Shoes were issued to subjects onboard three ships: the USS Deyo, USS Shenandoah, and USS Gunston Hall. Subjects onboard the USS Shenandoah received only CT shoes; USS Gunston Hall test participants received primarily Bates shoes (Approximately 94%, see table 22), while the USS Deyo participants received approximately 50% Bates and 50% CT shoes.

Shoes were worn for a total of five weeks in place of their regular military shoe, providing sufficient time for break-in and wearer accommodation to shoe characteristics. Shipboard preference questionnaires were completed at the end of the five weeks in the presence of NCTRF personnel.

Results

a. Data Analysis

Data from the preference questionnaires were summarized, and means and standard deviations were calculated. Open-ended questions were analyzed, and common responses were tallied. The data were analyzed using two standard statistical procedures. The Pearson Chi Squared (χ^2) statistic, was applied to dichotomous data, while a two-way Analysis of Variance (ANOVA) with shoe type (Bates vs CT) and Gender (Male vs Female) serving as between-subject factors, was used in the analysis of scale and continuous data. Results were deemed significant when the confidence level was equal to or greater than 95% ($P \leq 0.05$).

b. Demographics

In order to fairly compare the Bates and CT shoes, it was important to have subjects whose shoes fit correctly. Using the overall fit rating in the preference questionnaire, those subjects who rated the overall fit of their issued shoe as "just right" were identified. Only their data were included in the analysis. Of the original 95 subjects considered for the analysis approximately 78% were fit well (A total of 74). Table 23 shows the overall fit ratings by shoe type and gender.

Table 23: Ratings of Overall Fit

	Bates		CT	
	M	**F**	**M**	**F**
Good	24	8	25	17
Bad	4	8	5	3*

(Good="Just Right" Bad="Too Loose" OR "Too Tight")
* 1 Subject did not rate overall fit

The fit rate for male test participants is consistent for each ECS. The female fit rate however, for the Bates shoe is significantly different from that of the males (χ^2=5.13, n=16, df=1, p=0.023), with 50% of the female subjects reporting a "bad" fit. Of the women who were found to have a "bad" fit, 50% (n=4) stated that the shoe was "too loose" and 50% stated that the shoe was "too tight". This suggests a problem in the initial fitting of the shoes, rather than any problem with the shoe itself.

c. Fit Assessment

Table 24, shows the reported frequency with which test participants wore the shoes. Approximately three-quarters of the subjects wore the ECSs every day. The wear pattern is consistent between the Bates and CT shoes for both male and female. The median average wear time for both shoes was listed as being 7 to 9 hours. Inserts were rarely utilized, with only three participants using them.

Table 24: Wear Pattern

	Bates		CT	
	M	**F**	**M**	**F**
Wear Every Day	19	7	18	13
Do Not Wear Every Day	5	1	7	4

Eight factors were used to assess the fit of the shoe: ease of donning, ease of doffing, fit of ankle, fit of toes, fit of heel, fit of instep, arch support, and ankle support. All fit factors were rated positively. However, a two-way ANOVA revealed that mean responses for two factors, fit of the ankle and fit of the heel were rated differently.

The fit of the ankle was found to be significantly different (F=5.05, df=1,68, p=0.02) between the ratings of males and females for both shoes. Both the Bates and CT shoes were rated slightly "too tight" by the females ($\bar{x}$=1.75, 1.88, respectively) while the males rate the fit as "just right" ($\bar{x}$=2.00, 2.00, respectively).

The ratings for the fit of the heel were found to be significantly different between the Bates and CT shoes (F=9.273, df=1,68 p=0.003; $\bar{x}$=2.13, 2.00, respectively) and between the responses of males and females (F=5.619, df=1,68 p=0.021; $\bar{x}$=2.02, 2.12, respectively).

d. Ability to Perform Activities

Wearers' ability to perform various activities was measured by ratings of ability to stand, walk, run, march, descend ladders, and ascend ladders. Table 25, shows the mean rating for each factor. An ANOVA revealed no significant differences between mean responses for either shoe, regardless of gender.

Table 25: Mean Ratings of Factors Assessing Wearers' Ability to Function

	Bates		CT	
	M	F	M	F
Ability to Stand	2.88	2.88	2.88	2.71
Ability to Walk	2.96	3.00	2.96	2.88
Ability to Run	2.38	2.75	2.68	2.63
Ability to March	2.75	3.00	2.91	2.86
Descend Ladders	2.75	2.88	2.84	2.82
Ascend Ladders	2.75	2.88	2.88	2.82

1.00=Poor, 2.00=Fair, 3.00=Good

Shoe performance was further characterized by rating each shoe's traction on a number of surfaces. Table 26 presents the mean ratings for traction.

Table 26: Traction Ratings for Different Surfaces

	Bates		CT	
	M	F	M	F
Wet/Moist	2.68	2.75	2.92	2.88
Oil Covered	2.39	2.50	2.44	2.83
Waxed	2.86	2.71	2.91	3.00
Nonskid	2.96	2.88	3.00	3.00
Painted	2.86	2.83	2.88	3.00
Carpet	3.00	2.88	2.95	3.00
Steel Ladder Treads	2.88	2.75	2.84	3.00
Smooth Steel Decks	2.77	2.75	2.79	3.00

1.00=Poor, 2.00=Fair, 3.00=Good

Both the Bates and CT shoes were found to provide generally good traction on all surfaces. No significant differences were found among any rating.

e. Comfort

Comfort was measured by three factors: break-in period, ability of shoes to keep feet dry, and thermal comfort. The break-in times for both Bates and CT shoes are quite short with mean break-in times, between shoe type and gender, varying from 2.70 to 3.88 days. No significant differences were found among the ratings.

Both shoes were found to keep wearers' feet dry most of the time. Approximately 53% of the ECSs became wet during their wear time. Of the subjects whose shoes got wet, 85% found that the Bates and CT shoes adequately kept their feet dry. The remaining 15% stated that their feet became wet.

The mean thermal comfort rating of the Bates and CT shoes was close to "just right" for each shoe ($\bar{x}$=1.91, 1.86 respectively; scale: 1=Too Warm, 2= Just Right, 3=Too Cold). A two-way ANOVA found no significant differences between the ratings of either shoe or between male and female subjects. Although the mean rating was close to "just right", test participants from the Bates and CT groups found that the ECSs did not breathe, and retained moisture. Nineteen percent of Bates and 28% of CT wearers said that their feet had perspired and remained wet.

f. Medical Problems

The percentage of test participants experiencing medical problems is displayed in Table 27, along with the tally of the medical problems reported. In detailing the type of medical problem experienced, each subject was able to check all problems that occurred. Thus, in some instances, subjects reported more than one medical problem.

Table 27: Medical Problems Experienced

	Bates (N=32)	CT (N=42)
Medical Problems	22% (n=7)	26% (n=11)
Blisters	2	6
Foot Cramps	-	1
Aching Legs	-	1
Callouses	3	3
Aching Feet	1	3
Aching Back	1	2
Other	2	1

Note: Other includes: Tender/Aching Toes, Sore/Rubbed Ankle, Tender Heels, and Unspecified problems.

The frequency of medical problems was similar for both ECSs. Although a number of medical problems were reported, none of these required medical attention, and most problems reportedly went away after the break-in period.

g. Durability

The frequency of sustaining some form of damage by ECSs is shown in Table 28.

Table 28: Frequency of Damage to Shoes

	Bates		CT	
	M	**F**	**M**	**F**
Damaged	8	4	6	6
Not Damaged	20	12	23	15

Approximately 27% of Bates shoes and 24% of CT shoes were damaged in some way. Table 29, summarizes the problems and frequency of occurrence for each shoe.

Table 29: Summary of Damage to Shoes

	Bates	CT
Heel Starting to Separate	2	4
Sole Starting to Separate	-	2
Rip/Cut/Scuffed Leather	10	6

h. Acceptability

Acceptability of the ECSs was measured by a number of factors; the style of the shoes, an overall rating, and willingness to purchase the ECS. In addition, open-ended questions asked for users to list their most favored and least favored features.

The mean style and overall ratings are presented in Table 30.

Table 30: Mean Style and Overall Ratings

	Bates		CT	
	M	F	M	F
Style	4.33	4.00	4.33	4.41
Scale: (1=Really Dislike, 3=Fair, 5=Really Like)				
Overall Rating	4.23	4.13	4.40	4.24
Scale: (1=Very Poor, 3=Fair, 5=Excellent)				

The mean ratings for the ECSs were rated similarly on both the style scale, and on the overall rating, with all ratings above "good". A two-way ANOVA found no significant differences.

Table 31 shows the number of test participants who would or would not buy the ECS which they had worn.

Table 31: Purchase of Enhanced Chukka Shoes

	Bates		CT	
	M	F	M	F
Would Purchase	17	8	18	15
Would Not Purchase	5	0	7	2

Over 78% of respondents stated that they would buy one or other of the shoes if given the opportunity. Most of those who did not want to buy them reported they had already found a shoe/boot which they preferred.

Tables 32 and 33 list the tallied open-end responses for the most liked and most disliked features of the shoes. Please note that subjects could report as many features as they liked.

Table 32: Most Commonly LIKED Features

	Bates	CT
Roll Cuff/Ankle Cushion	8	11
Ankle Support	2	3
All	2	4
Tongue	2	4
Sole	1	2
Weight	1	1
Inserts	1	1
Leather	-	1
Arch fit	-	1

Table 33: Most Commonly DISLIKED Features

	Bates	CT
Tongue	3	3
Sole/Hard	1	3
Laces/Lace Holes	1	3
Steel Toe	-	2
Not High Enough	-	1
Roll Cuff	-	1

Discussion

The shipboard wear test aimed to identify any major problems and user acceptance of both the Bates and CT shoes in an operational setting. The results of the preference survey indicated that neither shoe had a negative impact on the user. Both shoes were rated positively in the areas of fit, users' ability to run, walk, march and walk, traction over different surfaces, looks, and overall ratings. Break-in times were short, between two and four days. The thermal comfort of the shoes were found to be "just right", and on the whole, kept the wearers' feet dry.

While both ECSs caused minor medical problems, such as blisters, these problems were not found to be lasting since they generally cleared up after the shoes were broken in. Also, no subjects needed professional medical treatment for these ailments.

With respect to comfort, the only problem experienced was in the breathability of the shoes. Nineteen percent of Bates and 28% of CT wearers said that their feet had perspired and remained wet.

In general, there were very few differences between the Bates and CT shoes. On almost all points of comparison the shoes were identical. In fact, the only question where a statistical difference occurred between the shoes was for the fit of the heel with mean ratings for the Bates and CT of 2.13 and 2.00, respectively. This statistically significant result should be put in perspective. The rating scale for both questions was: 1=Too Tight, 2=Just Right, 3=Too Loose. Therefore the differences between the ratings are minimal, at best, and do not necessarily imply there was a real fit problem.

There were very slight differences in the responses of males and females to the two shoes. The only statistical differences were for the fit of the ankle and the fit of the heel. In the case of the fit of the ankle, the mean female rating was slightly tighter than that of the males; whereas for the fit of the heel, the mean female rating was slightly looser. Again, the differences between the mean rating scores were so small that they have very little practical meaning.

One factor that could be further investigated is the durability of the shoes. The Bates and the CT shoes both showed some durability problems while in use onboard ship, especially in the area of the heel separating from the sole. Although the number of incidences of this problem is fairly small, it is unclear why these problems occurred.

The results of the shipboard study indicated that the Bates and CT shoes are good replacements for the present Chukka shoe. Both shoes were rated positively or found to be acceptable for all of the six areas of the investigation for operational use.

Conclusions

Overall, there were few differences between the two candidates, and those that occurred were minor. Both the Bates and the Craddock-Terry candidates were received favorably by the three test groups. Individually, both the Bates and the Craddock-Terry ECSs performed well and received positive ratings on the major test factors, such as the fit of the shoe, comfort, durability, acceptability, and users' ability to perform activities while wearing the ECSs. All other ratings on fit criteria, including the ankle support, break-in time, and insert usage, were rated positively by all groups.

When comparing the test groups, the findings were consistently equal, with the exception of the RTC group. The RTC group varied from the other two groups on two ratings: arch support, and the ability to don and doff the ECSs. The RTC group rated the arch support as "fair", compared to the RDC and shipboard groups more positive ratings of the ECSs on this criterion. The RTC group also rated the Craddock-Terry shoe as more difficult to don and doff compared to the Bates shoe. The RDC and the shipboard groups did not report these difficulties donning and doffing the Craddock-Terry. However, the RTC group alleviated this problem by fully unlacing their shoes to get them on and off.

Ventilation of the ECSs to alleviate sweat was a common comfort issue for both ECS candidates. Approximately 30% of the RDC and shipboard participants, and 40% of the RTC group experienced consistent sweating and wetness of feet. This is most likely a trade-off with this type of footwear, which must provide safety and durability with a thick leather construction, and also prevent user discomfort from sweating.

A major point of interest in this evaluation was to measure the incidences of foot problems for both ECSs. Both candidates were deemed acceptable by users, and good candidates for the replacement of the standard Chukka shoe. The reported problems received by the test participants were minor and decreased during the test period. In fact, medical personnel from the RTC reported that the incidence of problems was lower than the number normally received for the standard Chukka shoe.

A durability issue arose during the evaluation which is currently being addressed by the Bates and Craddock-Terry manufacturers. Both candidate shoes had problems with the heel separating from the shoe. In some instances the heel separated completely, and in most cases only partially.

The manufacturers are currently modifying the heel attachment method to correct this problem in the future.

In conclusion, this study determined that the Bates and Craddock-Terry candidates are equal performers in all operational settings, both land and shipboard. Both ECSs received positive ratings from test participants and are good candidates for replacing the standard Chukka shoe.

Appendix A

Recruit Enhanced Chukka Shoe Survey

Enhanced Chukka Shoe Survey

Date________________ **Questionnaire Number**________

1. **Last Four** _-_-_-_ **B** **C**

2. o **Male** o **Female**

3. **Date Of Birth** _____________

4. A. Rate the ease of putting on the Enhanced Chukka Shoes:

   o **Easy** o **Fairly Easy** o **Fairly Difficult** o **Difficult**

   Please explain any problems:

   B. Rate the ease of taking off the Enhanced Chukka Shoes:

   o **Easy** o **Fairly Easy** o **Fairly Difficult** o **Difficult**

   Please explain any problems:

   C. Rate the fit of the Enhanced Chukka Shoes in the following specific areas:

Ankle:	o Too Tight	o Just Right	o Too Loose
Toes:	o Too Tight	o Just Right	o Too Loose
Heel:	o Too Tight	o Just Right	o Too Loose
Instep(top of foot):	o Too Tight	o Just Right	o Too Loose

   D. Rate the overall fit of the Enhanced Chukka Shoes:
   o **Too Tight** o **Just Right** o **Too Loose**

5. A. Do you wear the Enhanced Chukka Shoe every day?

o **Yes** o **No**

If *NO*, how many days have you worn them? ______

B. Approximately how many hours per day have you been wearing the Enhanced Chukka shoes?

o **1-3** o **4-6** o **7-9** o **10+**

C. What other footwear have you worn during this evaluation?
Please list below:

6. A If you wear more than one pair of black issue socks with the Enhanced Chukka Shoes, how many pairs of each type do you wear?

o **White athletic socks** **number of pairs** ____
o **Black issue socks** **number of pairs** ____

B. Why?

7. Did you wear additional inserts or cushioning in your Enhanced Chukka shoes? o **Yes** o **No**

If *YES*, explain:

8. A. Rate the Enhanced Chukka Shoe's arch support.

o **Poor** o **Fair** o **Good**

B. If ***Poor*** or ***Fair***, please explain:

9. A. Rate the Enhanced Chukka Shoe's ankle support.
o **Poor** o **Fair** o **Good**

B. If ***Poor*** or ***Fair***, please explain:

10. Rate your ability to perform the following activities while wearing the Enhanced Chukka Shoe:

Stand..........................	o Poor	o Fair	o Good	o N/A
Walk...........................	o Poor	o Fair	o Good	o N/A
Run............................	o Poor	o Fair	o Good	o N/A
March..........................	o Poor	o Fair	o Good	o N/A

11. Rate the Enhanced Chukka Shoe's traction on the following surfaces:

Wet/Moist..............................	o Poor	o Fair	o Good	o N/A
Oil Covered (POL).................	o Poor	o Fair	o Good	o N/A
Waxed (tile deck).................	o Poor	o Fair	o Good	o N/A
Non-skid	o Poor	o Fair	o Good	o N/A
Painted	o Poor	o Fair	o Good	o N/A
Grass	o Poor	o Fair	o Good	o N/A
Mud	o Poor	o Fair	o Good	o N/A
Pavement	o Poor	o Fair	o Good	o N/A
Carpet	o Poor	o Fair	o Good	o N/A
Wooden surface floors	o Poor	o Fair	o Good	o N/A

12. A. Did your Enhanced Chukka Shoes get wet?
o **Yes** o **No**

******* IF NO, PROCEED TO QUESTION 13 *******

If ***YES:***

B. Did your Enhanced Chukka Shoes keep your feet dry?
o **Yes** o **No**

C. Approximately how long did it take them to dry completely?
o 1-3 Hours   o 4-6 Hours   o 7-9 Hours   o10+Hours

D. How did you dry them (air-dry naturally, etc.)?
Please explain:

13. Rate the thermal comfort (feet too warm or not warm enough) of the Enhanced Chukka Shoe.
o Too Warm   o Just Right   o Too Cold

If ***Too Warm***, are they too warm:

oAll of the time   o Some of the time
Explain:

If ***Too Cold***, are they too cold:

oAll of the time   o Some of the time
Explain:

14. Does the Enhanced Chukka Shoe cause your feet to sweat and stay wet?
o Yes   o No

15. A. Did the Enhanced Chukka Shoe cause any of the following problems (mark all that apply):

o None   o Blisters   o Foot Cramps   o Aching Legs
o Callouses   o Aching Feet   o Aching Back   o Other________

B. Did the problem continue? Please explain.

C. Did it require medical attention?
o Yes o No

If ***YES***, explain.

16. How many times did you have to wear the Enhanced Chukka Shoe to break it in?

- o Number of times _______
- o Did not need to be broken-in
- o Cannot be broken-in

17. Did your Enhanced Chukka Shoes get damaged (rips, tears, seams separate, etc.) during the evaluation? o **Yes** o **No**

If ***YES***, please indicate where on the picture below, and describe the problem.

18. Please rate the look of the Enhanced Chukka Shoe?

o 1	o 2	o 3	o 4	o 5
Really Dislike		***Fair***		***Really Like***

19. List any design features (example: sole, tongue, roll cuff) that you really **like**.

20. List any design features (example: sole, tongue, roll cuff) that you really **dislike**.

21. Please give an overall rating of the Enhanced Chukka Shoe.

o 1	o 2	o 3	o 4	o 5
Very Poor		***Fair***		***Excellent***

22. If given a choice, would you continue to wear the Enhanced Chukka Shoe after leaving the RTC? o **Yes** o **No**

If ***NO***, please explain:

23. Do you have additional comments/recommendations on the Enhanced Chukka Shoe?

Appendix B

RDC Preference Survey

Enhanced Chukka Shoe Survey

Date__________________ **Questionnaire Number**_________

1. **Last Four** __-__-__-__ **B** **C**

2. o **Male** o **Female**

3. **Date Of Birth** ______________

4. A. Rate the ease of putting on the Enhanced Chukka Shoes:

   o **Easy** o **Fairly Easy** o **Fairly Difficult** o **Difficult**

   Please explain any problems:

   B. Rate the ease of taking off the Enhanced Chukka Shoes:

   o **Easy** o **Fairly Easy** o **Fairly Difficult** o **Difficult**

   Please explain any problems:

   C. Rate the fit of the Enhanced Chukka Shoes in the following specific areas:

Ankle:	o Too Tight	o Just Right	o Too Loose
Toes:	o Too Tight	o Just Right	o Too Loose
Heel:	o Too Tight	o Just Right	o Too Loose
Instep(top of foot):	o Too Tight	o Just Right	o Too Loose

   D. Rate the overall fit of the Enhanced Chukka Shoes:
   o **Too Tight** o **Just Right** o **Too Loose**

5. A. Do you wear the Enhanced Chukka Shoe every day?

o **Yes** o **No**

If ***NO***, how many days have you worn them? ______

B. Approximately how many hours per day have you been wearing the Enhanced Chukka shoes?

o **1-3** o **4-6** o **7-9** o **10+**

C. What other footwear have you worn during this evaluation?
Please list below:

6. A If you wear more than one pair of black issue socks with the Enhanced Chukka Shoes, how many pairs of each type do you wear?

o **White athletic socks** **number of pairs** ____
o **Black issue socks** **number of pairs** ____

B. Why?

7. Did you wear additional inserts or cushioning in your Enhanced Chukka shoes? o **Yes** o **No**

If ***YES***, explain:

8. A. Rate the Enhanced Chukka Shoe's arch support.

o **Poor** o **Fair** o **Good**

B. If ***Poor*** or ***Fair***, please explain:

9. A. Rate the Enhanced Chukka Shoe's ankle support.

o **Poor** o **Fair** o **Good**

B. If ***Poor*** or ***Fair***, please explain:

10. Rate your ability to perform the following activities while wearing the Enhanced Chukka Shoe:

Stand...........................	o Poor	o Fair	o Good	o N/A
Walk............................	o Poor	o Fair	o Good	o N/A
Run..............................	o Poor	o Fair	o Good	o N/A
March..........................	o Poor	o Fair	o Good	o N/A

11. Rate the Enhanced Chukka Shoe's traction on the following surfaces:

Wet/Moist..............................	o Poor	o Fair	o Good	o N/A
Oil Covered (POL)..................	o Poor	o Fair	o Good	o N/A
Waxed (tile deck)..................	o Poor	o Fair	o Good	o N/A
Non-skid	o Poor	o Fair	o Good	o N/A
Painted	o Poor	o Fair	o Good	o N/A
Grass	o Poor	o Fair	o Good	o N/A
Mud	o Poor	o Fair	o Good	o N/A
Pavement	o Poor	o Fair	o Good	o N/A
Carpet	o Poor	o Fair	o Good	o N/A
Wooden surface floors	o Poor	o Fair	o Good	o N/A

12. A. Did your Enhanced Chukka Shoes get wet?

o **Yes** o **No**

******* IF NO, PROCEED TO QUESTION 13 *******

If ***YES***:

B. Did your Enhanced Chukka Shoes keep your feet dry?

o **Yes** o **No**

C. Approximately how long did it take them to dry completely?
o 1-3 Hours **o 4-6 Hours** **o 7-9 Hours** **o10+Hours**

D. How did you dry them (air-dry naturally, etc.)?
Please explain:

13. Rate the thermal comfort (feet too warm or not warm enough) of the Enhanced Chukka Shoe.
o Too Warm **o Just Right** **o Too Cold**

If ***Too Warm***, are they too warm:

oAll of the time o Some of the time
Explain:

If ***Too Cold***, are they too cold:

oAll of the time o Some of the time
Explain:

14. Does the Enhanced Chukka Shoe cause your feet to sweat and stay wet?
o Yes **o No**

15. A. Did the Enhanced Chukka Shoe cause any of the following problems (mark all that apply):
o None o Blisters o Foot Cramps o Aching Legs
o Callouses o Aching Feet o Aching Back o Other_________

B. Did the problem continue? Please explain.

C. Did it require medical attention?
o Yes o No

If ***YES***, explain.

16. How many times did you have to wear the Enhanced Chukka Shoe to break it in?

o Number of times _______
o Did not need to be broken-in
o Cannot be broken-in

17. Did your Enhanced Chukka Shoes get damaged (rips, tears, seams separate, etc.) during the evaluation? o **Yes** o **No**

If ***YES***, please indicate where on the picture below, and describe the problem.

18. Please rate the look of the Enhanced Chukka Shoe?

o 1	o 2	o 3	o 4	o 5
Really Dislike		***Fair***		***Really Like***

19. List any design features (example: sole, tongue, roll cuff) that you really **like**.

20. List any design features (example: sole, tongue, roll cuff) that you really **dislike**.

21. Please give an overall rating of the Enhanced Chukka Shoe.

o 1	o 2	o 3	o 4	o 5
Very Poor		***Fair***		***Excellent***

22. If given a choice, would you continue to wear the Enhanced Chukka Shoe after leaving the RTC? o **Yes** o **No**

If ***NO***, please explain:

23. Do you have additional comments/recommendations on the Enhanced Chukka Shoe?

Appendix C

Shipboard Preference Survey

Enhanced Chukka Shoe Survey (SB)

Date________________ **Questionnaire Number**________

Ship ________________

1. **Last Four** _-_-_-_ **B C**

2. o **Male** o **Female**

3. **Date Of Birth** ____________

4. A. Rate the ease of putting on the Enhanced Chukka Shoes:

   o **Easy** o **Fairly Easy** o **Fairly Difficult** o **Difficult**

   Please explain any problems:

   B. Rate the ease of taking off the Enhanced Chukka Shoes:

   o **Easy** o **Fairly Easy** o **Fairly Difficult** o **Difficult**

   Please explain any problems:

   C. Rate the fit of the Enhanced Chukka Shoes in the following specific areas:

Ankle:	o Too Tight	o Just Right	o Too Loose
Toes:	o Too Tight	o Just Right	o Too Loose
Heel:	o Too Tight	o Just Right	o Too Loose
Instep(top of foot):	o Too Tight	o Just Right	o Too Loose

   D. Rate the overall fit of the Enhanced Chukka Shoes:

   o **Too Tight** o **Just Right** o **Too Loose**

5. A. Do you wear the Enhanced Chukka Shoe every day?

o **Yes** o **No**

If *NO*, how many days have you worn them? ______

B. Approximately how many hours per day have you been wearing the Enhanced Chukka shoes?

o **1-3** o **4-6** o **7-9** o **10+**

C. What other footwear have you worn during this evaluation?
Please list below:

6. A What type of socks are you wearing with the Enhanced Chukka Shoes, and how many pairs of each type do you wear?

o **White athletic socks** **number of pairs** ____
o **Black issue socks** **number of pairs** ____
o **Other:** ______________ **number of pairs** ____

7. Did you wear additional inserts or cushioning in your Enhanced Chukka shoes? o **Yes** o **No**

If *YES*, explain:

8. A. Rate the Enhanced Chukka Shoe's arch support.

o **Poor** o **Fair** o **Good**

B. If ***Poor*** or ***Fair***, please explain:

9. A. Rate the Enhanced Chukka Shoe's ankle support.

o **Poor** o **Fair** o **Good**

B. If ***Poor*** or ***Fair***, please explain:

10. Rate your ability to perform the following activities while wearing the Enhanced Chukka Shoe:

Stand..........................	o Poor	o Fair	o Good	o N/A
Walk...........................	o Poor	o Fair	o Good	o N/A
Run.............................	o Poor	o Fair	o Good	o N/A
March..........................	o Poor	o Fair	o Good	o N/A
Descending Ladders....	o Poor	o Fair	o Good	o N/A
Ascending Ladders......	o Poor	o Fair	o Good	o N/A

11. A. Rate the Enhanced Chukka Shoe's traction on the following surfaces:

Wet/Moist..............................	o Poor	o Fair	o Good	o N/A
Oil Covered (POL)..................	o Poor	o Fair	o Good	o N/A
Waxed (tile deck)..................	o Poor	o Fair	o Good	o N/A
Non-skid	o Poor	o Fair	o Good	o N/A
Painted	o Poor	o Fair	o Good	o N/A
Carpet	o Poor	o Fair	o Good	o N/A
Steel Ladder Treads	o Poor	o Fair	o Good	o N/A
Smooth Steel Decks	o Poor	o Fair	o Good	o N/A

B. Did temperature affect the traction of the shoes?
o **Yes** o **No**

If YES Please Explain:

12. A. Did your Enhanced Chukka Shoes get wet?
o **Yes** o **No**

******* IF <u>NO</u>, PROCEED TO QUESTION 13 *******

If ***<u>YES</u>:***

B. Did your Enhanced Chukka Shoes keep your feet dry?
o **Yes** o **No**

C. Approximately how long did it take them to dry completely?
o **1-3 Hours** o **4-6 Hours** o **7-9 Hours** o **10+Hours**

D. How did you dry them (air-dry naturally, etc.)?
Please explain:

13. Rate the thermal comfort (feet too warm or not warm enough) of the Enhanced Chukka Shoe.
o **Too Warm** o **Just Right** o **Too Cold**

If ***Too Warm***, are they too warm:

oAll of the time o Some of the time
Explain:

If ***Too Cold***, are they too cold:

oAll of the time o Some of the time
Explain:

14. Does the Enhanced Chukka Shoe cause your feet to sweat and stay wet?
o **Yes** o **No**

15. A. Did the Enhanced Chukka Shoe cause any of the following problems (mark all that apply):
o None o Blisters o Foot Cramps o Aching Legs
o Callouses o Aching Feet o Aching Back o Other________

B. Did the problem continue? Please explain.

C. Did it require medical attention?
o **Yes** o **No**

If ***YES***, explain.

16. How many times did you have to wear the Enhanced Chukka Shoe to break it in?

- o Number of times _______
- o Did not need to be broken-in
- o Cannot be broken-in

17. Did your Enhanced Chukka Shoes get damaged (rips, tears, seams separate, etc.) during the evaluation? o **Yes** o **No**

If ***YES***, please indicate where on the picture below, and describe the problem.

18. Please rate the <u>look</u> of the Enhanced Chukka Shoe?

o 1	o 2	o 3	o 4	o 5
Really Dislike		***Fair***		***Really Like***

19. List any design features (example: sole, tongue, roll cuff) that you really **like**.

20. List any design features (example: sole, tongue, roll cuff) that you really **dislike**.

21. Please give an overall rating of the Enhanced Chukka Shoe.

o 1	o 2	o 3	o 4	o 5
Very Poor		***Fair***		***Excellent***

22. Would you purchase the Enhanced Chukka Shoe if given the option?
o **Yes** o **No**

If ***NO***, please explain:

23. Do you have additional comments/recommendations on the Enhanced Chukka Shoe?

Appendix D

RDC Comparison Survey

Enhanced Chukka Shoe Comparison Survey

Date________________ **Questionnaire Number**________

1. **Last Four** __-__-__-__

2. o **Male** o **Female**

3. **Date Of Birth** _____________

4. Which Enhanced Chukka Shoe did you prefer?

   o**B** o**C** o **Same**

   Please explain.

   4a. Do you prefer this shoe to the standard issue Chukka Shoe (The shoe usually issued to new recruits)?

   o Yes o No

   Please explain.

5. Which shoe did you prefer for the following characteristics:

Fit...........................	oB	oC	oSame
Comfort................	oB	oC	oSame
Durability...........	oB	oC	oSame
Traction................	oB	oC	oSame
Thermal Comfort..	oB	oC	oSame
Water Repellency..	oB	oC	oSame

6. Which shoe did you prefer while performing the following:

Standing..............	oB	oC	oSame
Walking...............	oB	oC	oSame
Running...............	oB	oC	oSame
Marching.............	oB	oC	oSame

7. Which shoe did you prefer for comfort in the following specific areas:

Ankle:	o B	o C	o NO PREFERENCE
Toes:	o B	o C	o NO PREFERENCE
Heel:	o B	o C	o NO PREFERENCE
Instep(top of foot):	o B	o C	o NO PREFERENCE

8. Which shoe did you prefer for fit in the following specific areas:

Ankle:	o B	o C	o NO PREFERENCE
Toes:	o B	o C	o NO PREFERENCE
Heel:	o B	o C	o NO PREFERENCE
Instep(top of foot):	o B	o C	o NO PREFERENCE

9 A. Which Enhanced Chukka Shoe was easier to break in?
oB oC oSAME

B. Which Enhanced Chukka Shoe was easier to put on?
oB oC oSAME

C. Which Enhanced Chukka Shoe was easier to take off?
oB oC oSAME

10. List any design features of the Enhanced Chukka Shoes (example: sole, tongue, roll cuff) that you really **like**.

Enhanced Chukka Shoe **B**	Enhanced Chukka Shoe **C**

11. List any design features of the Enhanced Chukka Shoes (example: sole, tongue, roll cuff) that you really **dislike**.

Enhanced Chukka Shoe **B**	Enhanced Chukka Shoe **C**

12. Which shoe would you purchase?

B only
C only
Either one
Neither

13. Please rate how easily you were able to produce a shine for military-appearance on:

A. The BATES shoe

o 1	o 2	o 3	o 4	o 5
Very Difficult				Very Easy

B. The CRADDOCK - TERRY shoe

o 1	o 2	o 3	o 4	o 5
Very Difficult				Very Easy

C. Any further comments pertaining to the care and maintenance of either boot?

14. Do you have additional comments/recommendations on the Enhanced Chukka Shoes?

Appendix E

Recruit Demographic and Issue Questionnaire

Demographic Sheet

Date______________

Last Four __-__-__-__ B C

Date Of Birth ______________

o L o R

o Male o Female

Race: o American Indian oAsian oAfro-American oCaucasian oHispanic

1. Do you have any foot problems? oYes oNo
   If Yes, explain.

2. Measured (Brannock Device) Shoe Size:
   Left: length_________width__________
   Right: length________width__________

3. a. Issued Enhanced Chukka Shoe Size: length________width________
   Rate the fit: oToo Loose oJust Right oToo Tight

   b. If issued shoe size **did not** fit properly, and another size was issued:
   2nd Issued Enhanced Chukka Shoe Size:
   length________width________
   Rate the fit: oToo Loose oJust Right oToo Tight

   List any other shoe sizes that were tried, and rate the fit (as done above).

   c. If the test participant could not be properly fit with a shoe, explain why it was not possible.

---

4. **Fitted by:** ______________________________

5. **Measured by:** ______________________________

Appendix F

Turn In and Reissue Data Form

Turn In and Reissue Sheet

IF SHOES HAD TO BE EXCHANGED FOR ANOTHER SIZE AFTER BEING WORN, PLEASE COMPLETE THE FOLLOWING:

Date______________ **Last Four** __-__-__-__ **B** **C**

o **Male** o **Female** **Date Of Birth** ______________

1. Date shoes were turned-in_______________.
2. Size of shoes being turned-in_________________________.
3. Reason for turn-in:
4. Number of days the Enhanced Chukka Shoes were worn ___________.
5. If test participant was re-measured:

   Measured (Brannock Device) Shoe Size:
   Left: length_________width__________
   Right: length________width__________

6. Re-Issued Size of Enhanced Chukka Shoe: length________width_________
   Rate the fit: oToo Loose oJust Right oToo Tight

7. **Fitted by:** _______________________________
8. **Measured by:** _______________________________

Appendix G

Summary Data by ECS and Survey Number

Summary Data by Enhanced Chukka Shoe and Survey Number for Three-Point Scales

Rating Scale:	1=POOR		2=FAIR		3=GOOD	
	BATES			**CRADDOCK-TERRY**		
	Survey #1	**Survey #2**	**Survey #3**	**Survey #1**	**Survey #2**	**Survey #3**
Arch Support	$\bar{x}$=**2.44** SD=.66 N=126	$\bar{x}$=**2.33** SD=.67 N=120	$\bar{x}$=**2.39** SD=.69 N=117	$\bar{x}$=**2.40** SD=.68 N=108	$\bar{x}$=**2.13** SD=.78 N=109	$\bar{x}$=**2.14** SD=.75 N=115
Ankle Support	$\bar{x}$=**2.68** SD=.55 N=127	$\bar{x}$=**2.67** SD=.56 N=120	$\bar{x}$=**2.72** SD=.58 N=116	$\bar{x}$=**2.72** SD=.53 N=107	$\bar{x}$=**2.68** SD=.56 N=110	$\bar{x}$=**2.64** SD=.58 N=114

Summary Data by Enhanced Chukka Shoe and Survey Number for Three-Point Scales

Rating Scale: 1=TOO TIGHT 2=JUST RIGHT 3=TOO LOOSE						
	BATES			CRADDOCK-TERRY		
	Survey #1	Survey #2	Survey #3	Survey #1	Survey #2	Survey #3
Overall Fit	**x̄=2.03** SD=.38 N=126	**x̄=2.06** SD=.45 N=121	**x̄=2.09** SD=.38 N=117	**x̄=2.02** SD=.31 N=105	**x̄=1.97** SD=.44 N=110	**x̄=2.06** SD=.45 N=114
Ankle Fit	**x̄=2.05** SD=.36 N=125	**x̄=2.01** SD=.34 N=118	**x̄=2.09** SD=.40 N=116	**x̄=2.07** SD=.40 N=107	**x̄=2.07** SD=.42 N=106	**x̄=2.15** SD=.43 N=114
Toes Fit	**x̄=1.95** SD=.44 N=124	**x̄=1.92** SD=.53 N=118	**x̄=1.93** SD=.49 N=117	**x̄=1.92** SD=.46 N=107	**x̄=1.79** SD=.53 N=107	**x̄=1.92** SD=.52 N=115
Heel Fit	**x̄=2.14** SD=.39 N=123	**x̄=2.15** SD=.44 N=117	**x̄=2.10** SD=.33 N=116	**x̄=2.15** SD=.45 N=107	**x̄=2.11** SD=.44 N=106	**x̄=2.17** SD=.44 N=113
Instep Fit	**x̄=2.06** SD=.34 N=126	**x̄=1.97** SD=.39 N=115	**x̄=2.00** SD=.37 N=115	**x̄=1.93** SD=.38 N=106	**x̄=1.97** SD=.38 N=106	**x̄=1.94** SD=.41 N=113
Rating Scale: 1=TOO WARM 2=JUST RIGHT 3=TOO COLD						
	Survey #1	Survey #2	Survey #3	Survey #1	Survey #2	Survey #3
Thermal Comfort	**x̄=1.78** SD=.44 N=116	**x̄=1.69** SD=.47 N=118	**x̄=1.72** SD=.49 N=116	**x̄=1.88** SD=.45 N=105	**x̄=1.68** SD=.51 N=107	**x̄=1.75** SD=.44 N=114

Summary Data by Enhanced Chukka Shoe and Survey Number for Four-Point Scales

Rating Scale: 1=Easy 2=Fairly Easy 3=Fairly Difficult 4=Difficult						
	BATES			CRADDOCK-TERRY		
	Survey #1	Survey #2	Survey #3	Survey #1	Survey #2	Survey #3
Donning the ECS	$\bar{x}$=**1.49** SD=.63 N=128	$\bar{x}$=**1.52** SD=.58 N=122	$\bar{x}$=**1.45** SD=.53 N=117	$\bar{x}$=**1.94** SD=.73 N=108	$\bar{x}$=**2.13** SD=.64 N=110	$\bar{x}$=**2.05** SD=.68 N=117
Doffing the ECS	$\bar{x}$=**1.47** SD=.60 N=126	$\bar{x}$=**1.45** SD=.55 N=121	$\bar{x}$=**1.46** SD=.52 N=117	$\bar{x}$=**1.84** SD=.69 N=107	$\bar{x}$=**1.91** SD=.55 N=110	$\bar{x}$=**1.89** SD=.63 N=117

Summary Data by Enhanced Chukka Shoe and Survey Number for Five-Point Scales

Rating Scale: 1=Very Poor	3=Fair			5=Excellent		
	BATES			**CRADDOCK-TERRY**		
	Survey #1	**Survey #2**	**Survey #3**	**Survey #1**	**Survey #2**	**Survey #3**
Overall Rating of ECS	$\bar{x}$=**4.04** SD=.67 N=117	$\bar{x}$=**4.01** SD=.67 N=120	$\bar{x}$=**3.94** SD=.78 N=114	$\bar{x}$=**3.93** SD=.73 N=103	$\bar{x}$=**3.62** SD=.73 N=108	$\bar{x}$=**3.76** SD=.78 N=110
Rating Scale: 1=Very Poor	**3=Fair**			**5=Excellent**		
	Survey #1	Survey #2	Survey #3	Survey #1	Survey #2	Survey #3
"Look" Rating of ECS	$\bar{x}$=**4.45** SD=.71 N=127	$\bar{x}$=**4.36** SD=.77 N=115	$\bar{x}$=**4.37** SD=.73 N=115	$\bar{x}$=**4.31** SD=.73 N=105	$\bar{x}$=**4.22** SD=.80 N=105	$\bar{x}$=**4.03** SD=.97 N=115

Appendix H

Medical Information for Each ECS

Medical Information for each ECS type

Medical personnel were sought for the following problems:

Bates:
Blisters (N=3)
Ankle/foot pain (N=3)
Ingrown toenail (N=2)
Knee pain (N=2)
Sore feet (N=1)

Craddock-Terry:
Ankle pain (N=10)
Sore feet (N=6)
Blisters (N=4)
Chronic sore feet (N=2)

Appendix I

Memorandum from Medical Personnel

30 MAY 1996

TO WHOM IT MAY CONCERN;

THIS LETTER IS IN REGARD TO THE TWO NEW PAIRS OF BOOTS THAT WERE WEAR TESTED AT THE RECRUIT TRAINING CENTER GREAT LAKES, ILLINOIS OVER THE LAST THREE MONTHS. IN ADDITION TO THE FOUR DIVISIONS OF RECRUITS AND RECRUIT DIVISION COMMANDERS WHICH WORE THEM, MYSELF AND TWO OTHER GENERAL MEDICAL OFFICERS WORE BOTH PAIRS OF BOOTS. AFTER THE TEST WAS COMPLETED MYSELF AND THE TWO GENERAL MEDICAL OFFICERS MET TO DISCUSS THE NEW BOOTS AND FILL OUT OUR SURVEYS. WE UNANIMOUSLY FELT THAT BOTH PAIRS OF NEW BOOTS WERE FAR SUPERIOR TO THE BOOTS CURRENTLY IN USE. THE NEW BOOTS SEEMED TO BE OF A HIGHER QUALITY MATERIAL AND BETTER CONSTRUCTION AND DESIGN. THE LEATHER UPPER PART OF THE BOOT WAS VERY SOFT AND SUPPLE AND TOOK PRACTICALLY NO BREAK IN TIME, IT FELT LIKE IT WAS ALREADY BROKER IN THE FIRST TIME THE BOOTS WERE WORN. THE PADDING AT THE TOP OF THE BOOT, AROUND THE ANKLE, WAS ALSO VERY COMFORTABLE AND ADDED SUPPORT TO THE ANKLE JOINT. THE INSOLES AND PADDING ON THE INSIDE OF THE BOOTS WERE EXCELLENT. THIS SHOULD AID IN KEEPING THE FOOT DRY, COMFORTABLE AND WARM IN COLD WEATHER CONDITIONS. ANOTHER IMPROVEMENT IS THAT THE NEW BOOTS COME IN WOMEN'S SIZES TO FIT THEIR FEET INSTEAD OF MEN'S BOOTS TO FIT THEIR FEET WHICH IS CURRENTLY BEING USED.

FROM A MEDICAL STANDPOINT NONE OF THE THREE HEALTH CARE PROVIDERS DEVELOPED ANY BLISTERS, ABRASIONS OR FOOT PAIN WHILE WEARING THE NEW BOOTS NOR DID THERE APPEAR TO BE ANY INCREASED INCIDENCE OF FOOT COMPLAINTS FROM THE RECRUITS WEARING THE NEW BOOTS.

Arthur W. Ward

ARTHUR W. WARD
LCDR, USN, MSC
STAFF PODIATRIST
RTC GREAT LAKES

03959 9-20-96

Development of a Laboratory Rough Sea Simulation Method for Testing Protective Clothing

Navy Clothing and
Textile Research Facility
Natick, Massachusetts

NCTRF Technical Report No.__________

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13. ABSTRACT (*Maximum 200 words*)
The work reported in this document was undertaken to evaluate the effectiveness of various methods of rough sea simulation for testing the performance of garments designed to protect sailors from the hazard of body heat loss in the event of accidental immersion. Although ocean testing with human subjects can provide the most realistic conditions, this procedure is expensive, difficult to conduct safely and limited to certain times of the year. Some eight different methodolgies for producing water turbulence were installed and evaluated in the Navy Clothing and Textile Research Facility (NCTRF) hydro-environmental tank, including: water agitation by the metered release of compressed air; the pumped flow of water, and wave making. The effectiveness of the simulation methods was determined by measuring the heat lost by a thermal manikin (TM) wearing the full aviators anti-exposure ensemble. The water and air temperature were maintained at 15.5°C and the TM temperature was set at 20° C. This provided a thermal gradient within the limits which the TM could maintain at the expected immersed insulation clo values. The use of diffused compressed air to produce water agitation meets most of the requirements for simulation of heat loss in a rough sea environment using the NCTRF hydro-environmental tank.

14. SUBJECT TERMS
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SUMMARY

Accidental water immersion is a serious problem that threatens all sailors, especially in cold water since body heat loss will occur despite the use of protective garments. Several field studies have demonstrated the increased severity of heat loss in rough seas compared to calm water. Therefore, it is important to include the effects of wave motion and water currents in testing the performance of garments, which are designed to provide protection in the open sea. Although ocean testing can provide the most realistic conditions, the procedure is expensive, difficult to conduct safely, and limited to certain times of the year. Therefore, it is desirable to test in a controlled laboratory environment.

The work reported in this document was undertaken to evaluate the effectiveness of various methods of rough sea simulation in the hydro-environmental tank located at the Navy Clothing and Textile Research Facility (NCTRF). An initial survey was conducted on the characterization of rough sea states, and on the approaches used at other facilities to simulate ocean turbulence. Eight different methodolgies for producing water turbulence were installed and evaluated in the NCTRF hydro-environmental tank. Water agitation was based on the metered release of compressed air, the pumped flow of water, and wave making. The effectiveness of the simulation methods was determined by measuring the heat lost by a thermal manikin (TM) while wearing the full aviator's anti-exposure ensemble. Water and air temperature were maintained at 15.5°C. The manikin temperature was set at 20°C in order (1) to provide a temperature gradient between the manikin surface and the water temperature and (2) to stay within the performance limits of the manikin to maintain a uniform surface temperature at the expected immersed clo values.

The reproducible placement of the manikin in the water was essential for repeatability, and secure anchoring was required to prevent water induced movement. The measured immersed clo values decreased with: 1) increased air flow rate in both the diffuse and concentrated air methods, 2) increased water flow rate in the pumped water method and 3) increased number of standing waves. The diffused release of air was more effective in decreasing clo than the concentrated release of air. With the diffused release of air and the pumped water flow methods, it was possible to obtain a 77% decrease in clo from a baseline value of 0.29 clo to about 0.07 clo. The lowest value in the set of tests, 0.05 clo, was obtained with the wave maker.

Comparisons were also made with human testing previously conducted under rough sea conditions in the ocean at Cape May, NJ. Results of the comparison testing are summarized in this document and complete details of the physiological testing are given in a related document (8). Since a structural analysis indicated that standing waves could affect the integrity of the tank, the wave maker could not be used in this more extensive set of tests. The pumped water method was also excluded because the pumps could not be ground faulted for safety in testing with humans. Therefore, the testing was performed using variations of the Diffused Compressed Air Methodology, with subjects wearing the aviator anti-exposure ensemble. At 30 minutes immersion, body core temperatures dropped by an average of 1.9°C at Cape May, compared to 1°C in the NCTRF facility with an air flow of 12 standard cubic feet per minute (SCFM). Increasing the air flow to 13.5 SCFM, resulted in cooling rates matching the ocean tests, but the water agitation at this level

exposed the subjects to an unacceptable risk of aspiration, and is not recommended for routine testing, especially with untrained subjects. The difference between the laboratory at 12 SCFM and field results may be due to more extensive circulation of water through seals in the garment caused by waves in the open ocean and/or greater heat loss from the head. Nonetheless, it is concluded that the use of diffused compressed air to produce water turbulence in the NCTRF hydro-environmental tank can meet most of the requirements for simulating rough sea heat loss in testing with human subjects .

I. INTRODUCTION

Accidental water immersion, particularly during rough seas, is a serious problem that threatens the safety of all sailors. When immersed in cold water, body heat will be lost despite the use of protective garments. The heat loss depends upon several factors: water temperature; insulation performance of the protective garment; style of the garment (i.e., wet - allowing water contact with skin, or dry - preventing water contact with skin); body fat of the immersed individual, and body position and activity, etc. This heat loss is exacerbated by rough seas, which can flush water around and through the garment at a more rapid rate.

The U.S. Coast Guard (USCG) conducted a field evaluation of the cold water (11.1°C/52°F) thermal protection of various USCG operational protective garments (1,2) in calm and rough seas. The study demonstrated that when the loosely-fitted, wet-suit concept garments are worn, body cooling rates were 1.5 to 2.0 times higher in rough seas than in calm seas. The increased severity of body cooling rates in rough seas was also demonstrated in a comparison of ten protective garments carried out on human subjects and a manikin, by the Cord Group Limited for the Canadian Defense and Civil Institute of Environmental Medicine (3). It was determined that the drop in thermal protection due to turbulent versus calm water was 28.6% in human testing and 56.8% in manikin testing. The results of these studies emphasize the importance of including the effects of wave motion and water currents in testing the performance of garments which are designed to provide protection in the open sea.

There are several approaches which have been traditionally used for evaluating the thermal performance of protective garments: 1) the resistance to heat loss can be measured using a thermal manikin in a laboratory environment (4, 5, 6), but the data are hard to relate to the actual sea environment, 2) the core cooling rate of human subjects immersed in calm water can be determined in a controlled laboratory environment (4, 7), and 3) realistically, a field evaluation can be conducted under calm or rough sea conditions, such as those in the above referenced studies.

Although the field evaluation can provide the most realistic scenario, it is not always practical or desirable. The field evaluation must contend with the logistics involved in coordinating test subjects and boat crews as well as, supporting medical personnel to assure the safe and successful completion of the evaluation. Furthermore, these evaluations are expensive and can only be conducted at specific locations and at certain times of the year when the required sea and temperature conditions are met. Therefore, it is desirable to be able to conduct the evaluations in a controlled laboratory environment, which simulates in some degree, the rough sea conditions.

The Navy Clothing and Textile Research Facility (NCTRF) has a hydro-environmental tank that can be used for both human and thermal manikin testing of anti-exposure garments. The water temperature, as well as the air temperature, can be tightly controlled and pumps ensure that the water is well-stirred. Since the original design of the tank did not include the capability of simulating the water motion of rough seas, this facility previously was limited to the evaluation of protective

garments under calm water conditions.

Recently, NCTRF initiated a project to expand the capabilities of its facility by incorporating a method of water agitation which would simulate the accelerated heat loss experienced under rough sea conditions. Eight different arrangements for producing wave motion or water currents were installed and evaluated. The specific goal of this investigation was to determine the extent to which the effects of rough seas could be simulated in the laboratory as a means of improving the methodology for measuring body heat loss during water immersion in rough sea conditions. The background, design, and performance of these different methods of introducing water agitation are described in detail in this report. In addition, the procedures and the results of thermal manikin testing, which were used to evaluate the effectiveness of the different methods, are provided in this report. As part of this project, a comparison was also made between the results of physiological testing in the field at the USCG facility at Cape May, and the results of physiological testing in the NCTRF hydro-environmental tank. Only a brief description of the test conditions and the conclusions from these studies is presented here. The detailed description of the procedures and results of the field and laboratory testing with human subjects is provided in a related report (8).

II. APPROACH AND BACKGROUND

A. Overview

For this investigation, the plans were to: 1) perform a background study of sea states and sea simulators currently in use, 2) purchase, fabricate, and install rough sea simulators, 3) conduct a thermal manikin evaluation to determine which rough sea simulation technique results in the greatest body heat loss in the NCTRF hydro-environmental tank, 4) conduct a field evaluation with human subjects in open seas, under rough sea conditions, with human subjects in order to determine the thermal performance of three protective garments, 5) conduct a laboratory evaluation under simulated rough sea conditions with the same subjects and garments, and 6) compare the rate of heat loss in the field with the rate of heat loss in the laboratory under simulated rough sea conditions, in an effort to determine if the laboratory simulation methods can be correlated with rough sea states in the "open" seas.

B. Background Investigation

Numerous libraries were contacted in eastern Massachusetts, including the Massachusetts Maritime Academy Library and U.S. Army Natick Research, Development and Engineering Center's technical library. Information pertaining to the sea, sea states, and sea state scales, was sorted and reviewed. In addition, reports or literature that made reference to rough seas, turbulent water, or water agitation were reviewed to learn what methods researchers used in tests on the performance of protective garments with human subjects or a manikin. The following individuals were contacted to gain from their experiences in the application of water agitation for immersion testing: 1) Dr. J.R. Allan at the Royal Air Force Institute of Aviation Medicine, United Kingdom, 2) A. Bryant at the United States Naval Academy, 3) S. Callean at the David Taylor Model Basin, 4) J. Kaufman at the Naval Air

Development Command, and 5) Dr. R.S. Pozos at the University of Minnesota. The significant findings of this background investigation are discussed in the following sections of this report.

C. Sea State Scales

In order to understand the classification of the sea states, it is first necessary to understand the formation of waves in the seas. Waves are described by two broad classes: deterministic and spectral analysis (9). In the deterministic approach, the properties of a single wave are used for analysis. This method is widely used for analysis and simulation, even though there is rarely a uniform one-dimensional wave in the open seas. Waves are generated by several methods as illustrated in Table 1, and in general, waves will be multidimensional due to the action of the wind from several directions. The spectral analysis method accounts for the varied wave forms through an analysis of random waves. For the current project, the deterministic approach was adopted.

As a means of classifying the state of the seas, early navigators adopted a numerical system that identified the wind velocity and correlated this to various sea states. Sir Francis Beaufort was the first to provide a formal scale on sea states that was widely adopted. In 1805, he devised a sea state scale which graduated from 0 to 12 with increasing wave intensity. Since that time, the Beaufort Scale, as it has become known, has been expanded to include sea states from 0 to 17 (Table 2). Another sea state scale that has been used is the International Scale, or Douglas Scale. According to the Douglas Scale the seas are considered to be calm up to a Beaufort number of 4, when the mean wave height in Table 2 does not exceed 1.0 meters (3.3 feet). Limited information was found on the International Scale, and apparently not widely used today.

The occurrence of wave intensities in the open sea throughout the world, has been measured and given a frequency of occurrence. Table 3 shows the distribution of wave heights for various sea locations. The tabulated numbers give the percentages for the occurrence of waves of the particular range in each respective ocean. Considering the whole ocean, in order to model 50% of the wave heights that occur, wave heights up to 1.5 meters (4.9 feet) would be needed. This would correspond to a Beaufort number between 4 and 5 in Table 2.

D. Currently Used Simulation Techniques

To determine the best method(s) of simulating sea states in a controlled environment, the simulation devices at several facilities were examined. Table 4 lists several of the agencies and institutions which were surveyed, the type of wave or turbulence generator at the location, and the primary function that the facility serves.

An examination of Table 4 shows that the wave simulation techniques can be divided into two major categories. In the first category, the facilities utilize their wave generator for the evaluation of wave action on sea structures. Dimensional analysis is used extensively at these facilities, thus, enabling them to simulate larger sea states with much smaller waves through scaling. Although their methods of wave generation and scaling produce the desired results, these techniques are not appropriate for

the NCTRF facility, since NCTRF must test at full scale. Also, most of these facilities have long tanks to allow a wave generated at one end to completely dissipate before reaching the other end. In the NCTRF hydro-environmental tank, which is 4.6 meters (15 feet) long, it is not possible to generate a wave of significant size at one end and have it completely dissipate before reaching the opposite end. Without complete dissipation, there would be significant disruption of the succeeding waves due to wave reflection.

The second category of facilities listed in Table 4 generates waves to evaluate the effect that the moving water has in dissipating heat from human subjects by disrupting the surrounding hydrothermal boundary layer. Hermann (10) has conducted tests of subjects immersed in a tank with a wave generating device capable of producing standing waves up to 0.8 meters in height. Standing waves, as opposed to traveling waves, occur with stationary nodes and oscillate within the tank, rather than traveling down the tank. This technique could be used in the NCTRF hydro-environmental tank. Allan (6) has also generated standing waves of up to 0.5 meters in height.

Several investigators believe that the critical factor in the action of rough or open seas is the flow of water over the individual and not specifically the height of the wave (10,11). This concept provides an alternative means of simulating rough seas. It involves techniques for disrupting the hydrothermal boundary layer with a water current, to simulate the effect of the open sea. Allan (6) and Kaufman (11) have simulated the action of a rough sea through the release of air below the surface of the water using a compressor. This causes turbulent agitation of the water surface and a reduction of the hydrothermal boundary layer surrounding the individual. This technique could easily be duplicated in the NCTRF hydro-environmental tank. Pozos (12) has conducted tests using a pool circulator (Swim Ex Systems, Inc. Warren, RI) that generates surface agitation and a current of up to 2.2 m/sec (7.2 ft/sec).

Referring to Table 4, and examining wave heights (peak to peak) developed in these facilities, it can be seen that they range from 0.18 to 0.9 meters (0.6 to 3.0 feet). According to the Beaufort Scale, Table 2, this range of wave heights corresponds to Beaufort Sea State Scale ranging from number 2 to number 3.

E. Modeling in the NCTRF Hydro-Environmental Tank

The Navy Clothing and Textile Research Facility hydro-environmental tank has a chamber that rests on a tank measuring approximately 4.6 meters long, 2.7 meters wide and 2.4 meters deep (15 x 9 x 8 feet) (Figure 1). The tank walls are insulated with fiberglass to reduce heat loss through the walls. The insulated test chamber, located over the tank, measures 6.7 meters long, 4.3 meters wide and 2.6 meters high (22 x 14 x 8.5 feet). The environment in the test chamber is controlled by four air handlers. Each air handler contains two cooling coils driven by a compound, single-stage, water-cooled compressor and three 2-kilowatt (kw) air heaters for conditioning the air in the chamber. The water temperature conditioning system consists of a 36-kw water heater, a compound, single-stage, water-cooled compressor, a water pump, and the piping and valving required to transport the water between the tank and the conditioning equipment.

There are certain physical limitations placed on the ability to model sea states in the NCTRF hydro-environmental tank due to its physical size and construction, as well as the dedication to human testing which requires safe environmental conditions. To evaluate protective clothing, it is necessary to have the test subjects immersed in the tank without their feet touching the bottom of the tank at any time during the wave cycle. For this to occur, the minimum water level should be at least 1.2 meters (4 feet) deep. Also, to contain the water within the tank at all times, the maximum water level should not exceed 1.8 meters (6 feet). This provides a maximum wave height of 0.6 meters (2 feet), peak-to-peak, that can be attained in the NCTRF hydro-environmental tank. A 0.6 meter wave corresponds to a maximum Beaufort Sea State Scale of 3 in Table 2. From Tables 2 and 3, waves up to 0.6 meters will simulate approximately 20% of the waves in the open ocean.

Although the duplication of wave action would provide the most direct method of water agitation, the above analysis shows that the maximum producible sea state in the NCTRF hydro-environmental tank is limited. An alternative method of sea simulation that has been used by several researchers is the modeling of the water velocity at the surface. Since the action of rough seas on protective clothing is essentially the continuous movement of water over and through the clothing, several investigators have modeled the rough sea using the measured or calculated surface water velocity. Water velocity can rise from several types of motion. Velocity due to open ocean currents and velocity due to wave action are the major sources of motion. The velocity of the water due to open ocean currents is tabulated in Table 5. Average open ocean currents of 0.18 m/sec (0.6 ft/sec) have been experienced with values up to 0.52 m/sec (1.7 ft/sec).

The motion of the water due to wave action can be described using the following simplified analysis. A single wave is shown in Figure 2. The height of the wave is given by D and the period is given by L. During the wave cycle, a single water particle follows a circular path. The velocity of this water particle can be estimated by the general laws of motion. Assuming circular motion:

$$v = \frac{\pi D}{L}$$

where:

v = velocity of water particle (m/sec) $\quad$ D = height of the wave (m)
L = period of the circular path (sec) $\quad$ $\pi = 3.1416$

For a wave with a height of 0.3 meters and a period of 1 second, the velocity of the water would be 0.94 m/sec.

Thus, simulation of rough seas might be achieved by modeling the circulation currents that are produced by the waves, as well as the physical production of waves. Circulation currents would disrupt the hydrothermal boundary layer surrounding a test subject, in a manner similar to that experienced in the open ocean. Considering the physical limitations of the NCTRF hydro-environmental tank, the modeling of open ocean currents might be more feasible than wave generation as a method of simulating rough sea conditions.

III. LABORATORY TEST METHOD DEVELOPMENT

A. Rough Sea Simulation Methodologies

Four principal arrangements with various modifications, amounting to eight methodologies in all for simulating rough seas, were installed for evaluation in the NCTRF hydro-environmental tank. By utilizing and modifying existing equipment and fabricating new equipment, it was possible to create continuous water turbulence to simulate rough seas. The eight rough sea simulation methodologies are described as follows:

1. Compressed Air Methodology

A large air compressor was used to generate the air required to provide water agitation that disrupted the thermal boundary layer surrounding the subject (either the Thermal Manikin or a human test volunteer), and to flush water through the protective garment. Two methods for generating water agitation with compressed air were analyzed: a) diffused and b) concentrated. By metering 3, 6, 9, and 12 Standard Cubic Feet per Minute (SCFM) of compressed air into the pool, it was possible to generate four levels of water turbulence for each of the two methodologies described below. Air flow was metered with a Dwyer, RMC series, 0-30 SCFM air flow meter. The compressed air was released so that, as it reached the water surface, it was centered below the subject's head. Accordingly, the water flow was directed around the subject's head towards his feet.

a) Diffused Compressed Air Methodology

Diffused compressed air was generated by releasing controlled volumes of compressed air from an air line secured to the bottom of the pool (Figure 3). As the air rose, it expanded and created water agitation over a wide area but there was localization of turbulence within the vicinity of the compressed air as it rose and reached the surface. The observed water agitation with an air flow of 12 SCFM took the form of waves, 0.27 to 0.4 meters (0.9 to 1.3 feet) in height that dissipated and canceled as they reached the tank walls. This wave action corresponded to a Beaufort Sea State Scale of 2.

b) Concentrated Compressed Air Methodology

Concentrated compressed air utilized the same equipment and metering as the Diffused Compressed Air Methodology. The concentrated compressed air was produced by confining the compressed air to rise up through a 1.5 meter (5 ft.) length of 0.1 meter (4 in.) inside diameter polyvinyl chloride (PVC) drainage pipe. The compressed air was released at 0.3 meters (12 in.) and at 0.58 meters (23 in.) below the surface (Figure 4). Due to the concentration of the air in the pipe, an even greater disturbance was generated than in the diffused air methodology, and there was an acute localization of turbulence within the vicinity of the compressed air as it reached the surface. The agitation took the form of a 0.8 meter (2.6 ft.) wave which dissipated to a 0.18 meter (0.6 ft.) wave that reflected

off the sides of the pool walls. This wave action corresponded to a Beaufort Sea State Scale between 3 and 4.

2. Water Pump Methodology

Two 5 hp water pumps were driven by a 230-volt, 3-phase electric motor. Each pump was capable of delivering 450 gallons per minute (GPM), and were used to generate a surface current flow. The surface current flow disrupts the thermal boundary layer surrounding the subject and also flushes water over and/or through the protective garment. Three methods for generating this surface current were analyzed: a) current, b) spray, and c) current and spray combined. By metering 150, 300 and 450 GPM, three levels of water turbulence were generated for the current and for the spray methods. For the combined current and spray methodology, the output of both pumps in combination was metered at 300, 600 and 900 GPM, to generate the three levels of water turbulence. Flow was measured with Bell & Gossett flow meters, with a range of 100 to 500 GPM each. For each methodology, the pumped water was directed towards the subject, but not on the subject.

a) Water Pump, Current Methodology

The current was generated by pumping metered volumes of water through a PVC pipe (Figure 5). The water exited 0.025 meters (5 in.) below the water surface and two feet from the subject. As the water exited the PVC pipe, a surface current was generated that disrupted the water surface with wavelets but did not create any wave action. This wave action corresponds to a Beaufort Sea State Scale of 1.

b) Water Pump, Spray Methodology

The spray was generated by spraying metered volumes of pumped water through a PVC pipe (Figure 6). The pumped water exited the PVC pipe 1.4 meters (4.5 ft.) above the pool surface at a 65-degree angle downward toward the surface. As the pumped water exited the PVC pipe and hit the water surface, a surface current was generated with little or no wave action. This wave action corresponded to a Beaufort Sea State Scale of 1.

c) Water Pump, Current and Spray Combined Methodology

The combination current and spray was generated by utilizing the above two methodologies at the same time (Figure 7). Water agitation took the form of random wavelets less than 0.09 meters (0.3 ft.) in height. This wave action corresponds to a Beaufort Sea State Scale of 1.

3. T-Bar Wave Maker Methodology

The wave maker utilized the water movement generated by the standing wave(s) to provide water turbulence. The wave action disrupted the thermal boundary layer surrounding the subject and flushed water through the protective garment. A large air compressor was used to generate the compressed air required to drive the pneumatic piston of the wave maker (Figure 8). Attached to the bottom of the piston was a T-bar which displaced the water in the tank, creating a standing wave. An air regulator, which was separate from the supply air compressor, was used to regulate the pressure of the air supplied to the piston. A digital timer (Gralab, Model 900) was used to alternately apply electrical power to two solenoids. The solenoids, when switched on, directed compressed air to the piston, thus driving the T-bar up and down in the water to create the standing wave action.

Four levels of water turbulence were generated. By adjusting the digital timer and air regulator, various modes correlating to the number of standing waves and level of water turbulence were generated. The observed water surface agitation was as follows: level 1, a single 0.18 meter (7 in.) standing wave; level 2, a single 0.28 meter (11 in.) standing wave; level 3, two 0.3 meter (12 in.) standing waves, and level 4, three 0.28 meter (11 in.) standing waves. All wave heights were measured peak-to-peak. The corresponding Beaufort Sea State Scale ranged from 1 to 2.

Note: Prior to starting an investigation of the Wave Maker Methodology, a structural analysis of the tank was conducted by a contractor. It was determined that: 1) a 0.6 meter (2 ft.) peak-to-peak wave, over time, may be enough to cause fatigue cracks originating in weld defects, 2) continuous operation with a maximum wave height of 0.15 meter (0.5 ft.) should be quite safe, 3) continuous flexing of the tank walls due to wave action would contribute to the cracking of the fiberglass which reinforced the walls, and 4) random waves 0 to 0.6 meter (0 to 2 ft.) peak-to-peak would be less likely to cause damage than periodic waves of the same maximum height. The only recommendations were to install a window doubler to help reduce any sudden failures in this area and to reinforce the top edge of the tank to decrease the flexure. In order to provide the planned comparison of simulation methods, it was decided to conduct the Wave Maker Methodology evaluation with the thermal manikin. However, as a result of the structural analysis report, the Wave Maker Methodology would not be considered for any continuous use or future evaluations.

4. Vertical Displacement Methodology

The Vertical Displacement Methodology utilized the vertical movement of the subject in the water to provide water turbulence. The displacement disrupts the thermal boundary layer surrounding the subject and flushes water through the protective garment. The Vertical Displacement Methodology (Figure 9) utilized the same equipment as the T-Bar Wave Maker Methodology. The T-bar at the base of the piston was replaced with a small, 0.05 x 0.1 meter (2 x 4 in.) bar with a ring to attach a cable. The cable ran overhead through two pulleys that were attached to an I-beam and then back down to a swimmer's harness at the water surface. The subject was then secured in the swimmer's harness and allowed to float in a vertical position.

Four levels of turbulence were generated by vertically displacing the subject out of the water for a period of three seconds. The subject was displaced one, two, three and four times per minute, creating four levels of water turbulence. The resulting water surface agitation was very small. The small disruptions of the water surface due to the vertical displacement of the subject could not be classified as a wave action. This wave action corresponds to a Beaufort Sea State Scale of 0.

5. Combination Vertical Displacement Plus Diffused Compressed Air Methodology

The Combination Vertical Displacement Plus Diffused Compressed Air Methodology utilized equipment from both methodologies (Figure 10). A single constant vertical displacement at four times per minute was combined with the four levels of metered air (3, 6, 9, 12 SCFM) released into the pool as described above in the Diffused Compressed Air Methodology.

The resulting water agitation, developed by the compressed air and vertical displacement, disrupts the thermal boundary layer surrounding the subject. Water also flushes through the protective garment, due to the rising compressed air and the vertical displacement. The surface turbulence was mainly a result of the compressed air methodology, and very little was expected from the vertical displacement methodology. At 12 SCFM, water agitation took the form of waves, 0.27 to 0.4 meters (0.9 to 1.3 ft.) peak-to-peak, that dissipated and canceled as they reached the tank walls. This wave action corresponds to a Beaufort Sea State Scale of 2.

B. Thermal Manikin Evaluation Methodology

1. Thermal Manikin Description

The NCTRF immersible manikin has been described in a previous report (13). Since the publication of the original technical report, the data acquisition equipment and computer control program have been replaced to increase the speed of data collection and decrease the time to reach thermal equilibrium.

2. Clothing System

The clothing system was representative of protective garments that would be worn in a rough sea situation. The same protective clothing system was utilized for the evaluation of all rough sea simulation methodologies and consisted of the following articles of clothing:

Aviators Anti-exposure Ensemble: 100% cotton long underwear (shirt, trousers); Wool/cotton cushion sole socks; Aviation coverall, *Mustang* MAC12; Canvas top sneakers; Diver's neoprene, three-finger mitten; Hypothermia hood (3/16 neoprene surf cap); LPU-26/P, Survival Vest assembly (life vest), and Swimmer's harness (for support and safety).

3. Measurement of Clothing Insulation Performance

To determine the effectiveness of the various rough sea simulation methodologies, the manikin was used to measure the immersed clo value of the protective clothing system at the various levels of water turbulence. Clo is a standardized unit representing the insulation of clothing (14). The clo value determined under immersion conditions is a measure of the resistance provided by the clothing, to the flow of heat from the manikin to the water. Immersed clo was determined as follows (6.45 = units conversion):

$$clo = \frac{6.45\ SA\ (T_w - T_m)}{Q}$$

where:

T_w = water temperature, °C
T_m = mean manikin surface temperature, °C
Q = power required to maintain a constant manikin surface temperature, Watts
SA = surface area of the manikin, m^2

4. Test Methodology

The manikin evaluation of the various rough sea simulation methodologies was conducted with the manikin dressed in the protective ensemble described above. For the Compressed Air, Water Pump and Wave Maker Methodologies, the manikin was placed in a floating position that simulated a real-life scenario. The manikin was lowered into the tank with its ankles secured 0.18 meters (7 in.) below the water surface. Next, the manikin's position in the water was adjusted with a securing cable attached to the swimmer's harness, so that the water level was just at the middle of the shoulders with the manikin floating on its back. This procedure was repeated each day of the evaluation.

For the Vertical Displacement and Vertical Displacement Plus Diffused Compressed Air Methodology, the manikin was placed in a different position. After being dressed in the protective ensemble, the manikin was lowered into the tank and assumed a natural floating position of approximately 45°, with respect to the water surface. The manikin's head was out of the water but its shoulders were immersed. The cable, attached to the manikin with a swimmer's harness for vertical displacement, was secured to prevent the manikin from moving freely in the tank. Securing the manikin was required during all evaluations to prevent the manikin from being damaged by contact with the tank walls. Although the swimmer's harness was secured to the manikin for safety during the evaluations, it was not expected to restrict water flow through the protective clothing system.

During the manikin evaluation, the chamber environmental conditions were as follows:

Water and air temperature = 15.5°C (59.9°F)
Manikin temperature = 20 °C (68°F)

Wind speed at water surface = 0.3 m/s (0.6 mph)

The thermal manikin was maintained at a temperature of 20°C (68°F) for this evaluation. This temperature was chosen because the predicted power requirements at the expected immersed clo values exceeded the capacity of the manikin to maintain a uniform surface temperature for temperature gradients greater than 5°C (9°F). It is important to note that clo values are independent of the water and manikin temperatures. Hence, the clo values measured under these test conditions would apply at other temperatures as well.

For each evaluation, the manikin was dressed in the protective clothing system and then lowered into the tank and properly positioned based upon the specific rough sea methodology as described below. The tank circulator/filter system was turned on and power was applied to the thermal manikin and data collected every minute. Baseline thermal equilibrium in the calm water was reached in two hours (i.e., one hour to reach set point temperature and one hour of thermal stability). During the second hour, the immersed clo value changed by <0.02 clo and the average value during this period was taken as the baseline clo value. Since the baseline values were affected by the amount of the manikin surface in the water, a standard placement was established, as described above. The water temperature changed by <0.2°C; the air temperature changed by <2.0°C, and the total immersed clo changed by no more than 0.02 clo during any 30-minute test interval. Test interval averages were within 0.01 clo for the three consecutive runs.

Each rough sea methodology was tested at either three or four levels of water turbulence. An evaluation of each methodology at a specific turbulence level was considered complete when three successive, half-hour averages of immersed clo changed by <0.02 clo. After completing the evaluation at one level, the turbulence level was changed and the evaluation was initiated at the new level of turbulence.

5. Problems During Thermal Manikin Evaluation

Several problems were encountered during the thermal manikin evaluation. First, there was a problem in reproducibly positioning the thermal manikin in the water for the baseline clo measurement. Changes in the amount of thermal manikin surface area below the water surface caused variability in the baseline clo value. Great care was taken to duplicate the position of the manikin in the water for each evaluation in order to minimize the influence of varying immersed surface area.

Second, the forces on the thermal manikin due to the positioning in the NCTRF hydro-environmental tank and the safety and securing tethers, which were necessary to restrict motion of the manikin by the water agitation, could interfere with the repeatability of results. The safety of the thermal manikin also required that the manikin be secured to prevent damage by contact with the tank walls.

Third, during the T-Bar Wave Maker Methodology evaluation, it was found that the standing wave moved the manikin around a great deal. Due to the rigidity of the manikin, some freedom of

movement was required to prevent any damage from occurring to the manikin. However, there was still a great deal of force on the manikin, enough to occasionally break the securing and safety tethers.

IV. RESULTS

A. Overview

There are basically two wave simulation techniques in use today: wave generating devices and water current generating devices. Both approaches disrupt the hydrothermal boundary layer surrounding the immersed subject, and flush water over and through the garment being worn. The results of the background study of sea states indicated that the most widely used measure of wave height in the open ocean is the Beaufort Sea State Scale. Modeling of conditions in the NCTRF hydro-environmental tank indicated that the maximum utilizable wave height was two feet, peak-to-peak. This corresponds to a Beaufort Sea State Scale of 3 and represents 20% of the waves measured in the open ocean. It was also determined that water current, rather than wave motion, could be used to simulate rough seas and might be better suited to the limitations of the NCTRF facility. The following sections present the results of the laboratory evaluation using the thermal manikin. In addition, a brief summary is provided comparing results from testing with human subjects in the field and in the laboratory. Full details of the test procedure and results are contained in a recent report (8).

B. Evaluation of Simulation Methods Using the Thermal Manikin

The immersed clo values obtained on the thermal manikin during the evaluation of the various rough sea simulation methodologies are presented in Table 6. The immersed clo values measured with the thermal manikin decreased with increasing air flow rate, using the compressed air methodologies. The clo value, using the Diffused Compressed Air Methodology, changed by only 0.01 clo above 6 SCFM. The immersed clo values, using the Concentrated Compressed Air Methodologies, could not match those obtained with the diffused air. Only the Diffused Compressed Air Methodology reached a minimum value with increasing air flow rate. The clo value decreased from a baseline value of 0.29 clo to a final value of 0.08 clo, equal to a 72% reduction in clo.

The immersed clo, with the Water Pump Methodology, decreased with increasing water flow output from the pumps. Both the Water Pump, Current, and the Water Pump Current and Spray Methodologies attained a 0.07 immersed clo value with pump outputs of 450 GPM. This was a reduction of 76% below the baseline value. It was not obvious that a minimum value was reached; however, there was little change in immersed clo value due to the increased water flow with both pumps operating simultaneously. In fact, there appeared to be a slight, unexpected, increase in clo value when both pumps were used (comparing combined methodology to either the current or spray methodology alone).

The immersed clo value, measured with the T-Bar Wave Maker Methodology also decreased with

an increasing number of standing waves. Using level 3 of the wave maker, which produced three 0.28 meter standing waves, the minimum immersed value was 0.05 clo, a reduction of 83% below the baseline value. However, the clo did not appear to reach a minimum value. Note in Table 6 that level 2 matched the lowest immersed clo value measured with any other methodology (0.08 clo), and the level 4 result, 0.05 clo, was the lowest immersed clo value of any methodology tested.

The immersed clo value measured with the Vertical Displacement Methodology decreased with increasing frequency, from 1 to 4 times per minute. A minimum clo value was not obtained. The lowest clo value (0.16) was three times greater than the lowest clo value measured with the Wave Maker Methodology.

Combining the Diffused Compressed Air Methodology with the Vertical Displacement Methodology (at 4 cycles per minute), had no effect on the immersed clo value when compared to the Vertical Displacement Methodology alone. The clo value measured for the combination methodology was 0.16 clo, identical to the Vertical Displacement Methodology alone, regardless of the air flow rate used.

C. Repeatability

Definitive tests of repeatability of a simulation methodology were not conducted. However, there were several indications of a high degree of repeatability. During the evaluation of the Compressed Air and Wave Maker Methodologies, the thermal manikin broke away from the positioning and safety tethers, and was pushed outside of the area of water agitation by the compressed air, or was moving freely with the standing waves. The reduced water agitation and water movement in, around, and through the protective garment, resulted in the increase of the immersed clo value. However, once the thermal manikin was repositioned and secured in the tank, the immersed clo values returned to those recorded prior to the breaking of the tethers. During the evaluations at each level of water turbulence/agitation, the total immersed clo value changed by no more than 0.02 clo during a single 30-minute test interval and by <0.01 clo for the average of three consecutive 30-minute tests, once thermal equilibrium was reached. The stability of the immersed clo values during the evaluations also indicates that a high level of repeatability could be expected from any of the test methodologies.

D. Comparison of Field and Laboratory Physiological Testing

1. Field Testing Conditions

Physiological testing was conducted in April 1995 with eight Navy volunteers at the U.S. Coast Guard Station, Cape May, with conditions of water and ambient air temperatures at 10°C and wind speed of 4.5 m/s (10 mph). Each subject participated in three water immersions, wearing each of three different clothing ensembles: Coverall, Coverall plus Shorty Wet Suit, and Float Coat. Most of the subjects also participated in a series of six evaluations of rough sea simulation methods in the NCTRF test facility. In five of the six laboratory tests, the subjects wore the Coverall, and in one

test, the Float Coat, as noted in Table 7. The subjects' core and skin temperature were monitored over the duration of the test to determine the rate of heat loss, and to indicate if a subject had to be withdrawn from the test due to hypothermia.

2. Method of Rough Sea Simulation

The physical size of the NCTRF hydro-environmental tank permitted the testing of only two subjects at the same time. Water agitation during the laboratory evaluation was provided by the Diffused Compressed Air Methodology, described earlier. A second air compressor was utilized in order to provide water agitation to both test subjects. Compressed air was piped from the compressors, located outside of the test area, to an area just beneath the test chamber. The air was metered and directed to the tank floor where it was released. Metering the compressed air provided an even and continuous distribution of water agitation.

3. Schedule of Laboratory Test Conditions

Most of the subjects from the field testing at Cape May, participated in the set of six tests conducted in the NCTRF facility. Testing was conducted for six days, designated sequentially as NCTRF-1 to NCTRF-6, usually with some modification in the conditions of water agitation, as summarized in Table 7. Five of the tests were conducted with the Coverall and the final day's testing was carried out with the Float Coat. In an attempt to improve the duplication of the results of field testing, the compressed air flow rate was increase from 12 SCFM in NCTRF-1 to 13.5 in NCTRF-2. This resulted in increased cooling rates that agreed well with the field data; however, the increased water turbulence caused an unacceptable risk of aspiration. Therefore, for NCTRF-3, the air pressure was lowered to the original level. To offset the lower air flow rate, the air was directed (Directed Air) closer to the subject, but this did not increase the cooling rate. For NCTRF-4, the subjects were instructed to submerse their arms once every 60 seconds to increase flushing of water through the garment. This did not succeed in increasing the cooling rate, but these conditions were duplicated during NCTRF-5 on the following day as a test of the repeatability. For NCTRF-6, these same conditions were used with the Float Coat rather than the Coverall.

4. Comparison of Field and Laboratory Data

The Coverall alone was worn during five of the six tests in the NCTRF hydro-environmental tank but only once at Cape May. The use of the Coverall was emphasized because it had proved to be the most protective garment in the field tests, and therefore, would provide the most severe test of the rough sea simulation. Three analyses of variance were performed, all involving testing with the Coverall:

a. Cape May vs. NCTRF-1 and NCTRF-2 ($n = 8$)
b. Cape May vs. NCTRF-1, NCTRF-2 and NCTRF-4 ($n = 7$)
c. Cape May vs. NCTRF-1, NCTRF-2, NCTRF-4 and NCTRF-5 ($n = 6$).

In all cases, there were no significant differences in the core temperatures between Cape May and NCTRF-2 ($p>0.05$), which featured the increased turbulence in the NCTRF tests. By 30-40 minutes,

the decrease in core temperatures of the subjects was greater in the tests at Cape May and NCTRF-2 than NCTRF-1, NCTRF-4 or NCTRF-5. Also, thigh temperatures in the tests at Cape May and NCTRF-2 were significantly lower at all times than in the other tests, by an average of 4°C. There were no significant differences among Cape May and any of the NCTRF tests in chest, calf or back skin temperatures ($p>0.05$). Forearm temperature during Cape May and NCTRF-2, as well as NCTRF-4 and NCTRF-5 was significantly lower than with NCTRF-1, indicating the effect of the periodic arm immersion. NCTRF-2 forearm temperature was also lower than Cape May.

With the Float Coat, the decrease in temperature at Cape May, from 30 minutes on was significantly greater than at NCTRF ($p<0.05$). After 60 minutes of immersion, the change in temperature averaged -2.6°C for the Cape May and -1.1°C for the NCTRF tests. There were no significant differences in calf, chest, or forearm skin temperatures between the field and laboratory testing. Thigh temperature, however, was lower at all times during field testing, by an average of 3.3°C ($p<0.05$). From 30 minutes on, back temperatures were also lower during field testing, by an average of 2.4°C.

V. CONCLUSIONS

Of the various rough sea simulation techniques evaluated with the thermal manikin in the NCTRF hydro-environmental tank, the Compressed Air, Water Pump and Wave Maker Methodologies provided the greatest effect on clo, with an average 77% drop from baseline immersed clo value (0.29). The Vertical Displacement and Vertical Displacement Plus Compressed Air Methodologies provided a 45% drop from baseline immersed clo value. With the Vertical Displacement Methodology, moving the manikin through the water did not provide as great a level of water movement as forcing the movement of the water over and through the protective garment worn by the thermal manikin. Vertical Displacement Plus Compressed Air increased the water motion and interaction with the thermal manikin, but also forced the thermal manikin outside of the turbulent area. It was not possible to secure the thermal manikin in the water turbulence caused by the compressed air, since the thermal manikin had to be free to be vertically displaced.

There are several reasons for choosing Compressed Air Methodology as the technique of water agitation for the simulation of rough seas in the laboratory for human testing. The Wave Maker Methodology was excluded because of the possible effect on the structural integrity of the tank. Both the Water Pump and Compressed Air Methodologies can produce comparable minimum immersed clo values, 0.07 and 0.08, respectively; however, the pump operates on 208 volts, 3-phase power, which could not be ground faulted for electrical safety during human use. The Diffused Compressed Air Methodology reached a value that was within 0.01 clo of the minimum value with a compressed air flow of 6 SCFM, operating at 50% of its maximum capability. Therefore, a doubling of the air flow was within the capability, if needed to produce still greater levels of water agitation.

Based on the above factors, the Diffused Compressed Air Methodology was chosen for the comparison of physiological testing results in the field and in the NCTRF hydro-environmental tank. With one exception, the variations of the method used to simulate rough sea conditions in the

laboratory resulted in smaller cooling rates, that is less body heat loss, than the cooling rates experienced during the field testing. The one approach, involving an increase in the air flow rate from 12 to 13.5 SCFM to intensify the water turbulence, caused an unacceptable risk of water aspiration for routine use with untrained test subjects. The difference between the laboratory and the field data with the lower levels of water turbulence, may be due to a greater degree of flushing of water through the seals of the garment by waves in the open sea, and/or a greater heat loss from the head, rather than differences in the extent of disruption of the hydrothermal boundary layer around the subject. Nonetheless, the use of diffused compressed air to produce water agitation meets most of the requirements for simulation of heat loss in a rough sea environment using the NCTRF hydro-environmental tank. Further improvements in the method may be possible by better management of the distribution of the turbulent water or by respiratory protection of the test subject to permit the use of the higher air flow rates.

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APPENDIX A

Table 1. Properties of Ocean Surface Waves*

Wave Type	Period Range	Approximate Wavelength	Depth Class	Controlling Forces	Generating Forces
Capillary	<0.1 sec	0.8 inches	deep water	surface tension	wind
Ultragravity	0.1-1 sec	33 feet	deep water	surface tension plus gravity	wind
Gravity	1-30 sec	3.3-4,429 feet	deep water to shallow	gravity	wind
Infragravity	30 sec-5 min	0.8-37 miles	deep water to shallow	gravity and corolis	wind and gravity
Long Period	75 min	37-434 miles	transitional to shallow	gravity and corolis	storms and earthquakes
Ordinary Tidal	fixed period	6-12 miles	shallow	gravity and corolis	gravity, sun and moon
Transtidal	> 24 hr	> 12 miles	shallow	gravity and corolis	storms, sun sun + moon

* Anikouchine, W.A. and R.W. Sternberg, *The World Ocean, An Introduction to Oceanography,* Prentice-Hall, Inc., NJ, 1981, pp 226.

Table 2. Beaufort Wind Scale and Correlative Sea Disturbance Table

Wind Force (Beaufort)	Limits of Speed in Knots	Descriptive Terms	Coastal Criterion.	Sea Criterion 1939 (Provisional)	Probable Mean Height of Waves*
0	< 1	Calm		Sea like a mirror.	
1	1-3	Light air	Sufficient to give good steerage to fishing smacks with the "wind free."	Ripples with the appearance of scales are formed but without foam crests.	0.3
2	4-6	Light breeze	Fishing smacks with topsails and light canvas "full and by," make up to 2 knots.	Small wavelets, still short but more pronounced; crests have a glassy appearance and do not break.	0.6 (1.0)
3	7-10	Gentle breeze	Smacks begin to heel over slightly under topsails and light canvas; make up to 3 knots "full and by."	Large wavelets. Crests begin to break. Foam of a glassy appearance. Perhaps scattered white horses.	2.0 (3.3)
4	11-16	Moderate breeze	Good working breeze. Smacks heel over considerably on a wind under all sail.	Small wavelets becoming longer. Fairly frequent white horses.	3.3 (4.9)
5	17-21	Fresh breeze	Smacks shorten sail.	Moderate waves, taking a more pronounced long form; many foamy white horses are formed. (Chance of some spray).	6.6 (8.2)
6	22-27	Strong breeze	Smacks double-reef gaff-mainsails.	Large waves begin to form; the white foam crests are more extensive everywhere. (Probably some spray).	9.8 (13.1)
7	28-33	Moderate gale	Smacks remain in harbor and those at sea lie to.	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind. (Spindrift begins to be seen).	13.1 (19.7)
8	34-40	Fresh gale	Smacks take shelter if possible.	Moderately high waves of greater length; edges of crests break into spindrift. The foam is blown in well marked streaks along the direction of the wind.	16.4 (24.6)

Table 2. Beaufort Wind Scale and Correlative Sea Disturbance Table (continued)

Wind Force (Beaufort)	Limits of Speed in Knots	Descriptive Terms	Coastal Criterion	Sea Criterion 1939 (Provisional)	Probable Mean Height of Waves*
9	41-47	Strong gale		High waves. Dense streaks of foam along the direction of the wind. Sea begins to roll. Spray may affect visibility.	22.9 (32.8)
10	48-55	Whole gale		Very long waves with long overhanging crests. The resulting foam in great patches is blown in dense white streaks along the direction of the wind. On the whole the surface of the sea takes a white appearance. The rolling of the sea becomes heavy and shock like. Visibility is affected.	29.5 (41.0)
11	56-65	Storm		Exceptionally high waves. (Small and medium-size ships might for a long time be lost to view behind the waves). The sea is completely covered with long white patches of foam lying along the direction of the wind. Everywhere the edges of the wave crests are blown into froth.	36.1 (52.5)
12	64-71	Hurricane		The air is filled with foam and spray. Sea completely white with driving spray; visibility very seriously affected.	over 45.9
13	72-80				
14	81-89				
15	90-99				
16	100-108				
17	109-118				

* Wave height in feet. Figures in parenthesis indicate the approximate maximum height reached by about one wave in ten.

Table 3. Relative Frequency in Percent of Wave Heights at Various Ocean Locations*

Ocean	Wave Height (feet)					
	<3.3	3.3-4.9	4.9-6.6	6.6-13.1	13.1-20.0	>20.0
North Atlantic (Newfoundland to England)	20	20	20	15	10	15
North Pacific (Latitude of Oregon and South of Alaska Penn.)	25	20	20	15	10	10
South Pacific (West Wind Belt Latitude of Southern Chile)	5	20	20	20	15	15
Southern Indian (Madagascar and Northern Australia)	35	25	20	15	5	5
Whole Ocean	20	25	20	15	10	10

Note: the total of wave height frequencies at a given ocean location may differ from 100 percent due to rounding errors.
Grant, G.M. *Oceanography: A View of the Earth,* Prentice-Hall, Inc., NJ, 1982, pp 222.

Table 4. Survey of Wave Generating Facilities

No.	Facility	Driving Device	Tank Size (feet)	Facility Use	Wave Height*
1	Federal German Navy			Human	2.6
2	Naval Air Warfare Center	Compressed air		Human	
3	United Kingdom	Compressed air		Human	
4	United Kingdom	Paddle		Human	1.5
5	University of Minnesota	Circulation tank	12 x 18 x 5	Human	
6	Civil Engineering Lab	Paddle	Multiple tanks	Structures	
7	Cold Regions Lab	Paddle	Table top basin	Structures	0.6
8	David Taylor Research Center	Pneumatic chambers	140 x 10 x 5	Structures	2.0
9	David Taylor Research Center	Pneumatic chambers	1800 x 50 x 22	Structures	2.0
10	David Taylor Research Center	Pneumatic chambers	360 x 240 x 35	Structures	2.0
11	U.S. Naval Academy	Paddle	120 x 8 x 5	Structures	1.3
12	U.S. Naval Academy	Paddle	1.6 deep	Structures	
13	U.S. Naval Academy	Paddle	380 x 16 x 13	Structures	3.0
14	Waterway Experimental Station	Paddle	Multiple tanks	Structures	

*Wave height (peak to peak, in feet)

Table 5. Average Surface Currents in the North Atlantic Ocean in July (1)

Lat., °N	Long., °W	Dir., deg.	Speed, Naut*	Lat., °N	Long., °W	Dir., deg.	Speed, Naut*.	Lat., °N	Long., °W	Dir., deg.	Speed, Naut*
55	55	160	11	**45**	60	180	2	**35**	75	75	40
	50	180	15		55	210	5		70	70	40
	45	180	5		50	160	4		65	65	20
	40	10	4		45	60	10		60	60	70
	35	30	2		40	80	2		55	55	180
	30	50	3		35	100	3		50	50	230
	25	30	4		30	100	2		45	45	180
	20	50	3		25	80	3		40	40	160
	15	90	5		20	110	4		35	35	170
	10	90	6		15	130	4		30	30	140
					10	180	3		25	25	130
50	50	180	9						20	20	180
	45	150	7	**40**	70	50	1		15	15	180
	40	150	5		65	70	8		10	10	180
	35	40	2		60	70	11				
	30	60	5		55	80	13	**30**	80	80	360
	25	50	3		50	90	11		75	75	360
	20	80	3		45	70	5		70	70	360
	15	90	2		40	120	5		65	65	10
	10	100	1		35	130	4		60	60	360
					30	120	3		55	55	290
					25	130	4		50	50	360
					20	130	5		45	45	230
					15	140	4		40	40	240
					10	180			35	35	240
									30	30	240
									25	25	180
									20	20	220
									15	15	220

Table 5. Average Surface Currents in the North Atlantic Ocean in July (continued)

Lat., °N	Lat., °N	Long., °W	Speed, Naut*	Lat., °N	Long., °W	Dir., deg.	Speed, Naut*	Lat., °N	Long., °W	Dir., deg.	Speed, Naut*
25	80	40	60	**15**	80	320	22	**5**	50	320	15
	75	320	6		75	280	17		45	90	12
	70	310	4		70	300	9		40	30	16
	65	310	3		65	300	12		35	70	20
	60	300	4		60	310	12		30	70	13
	55	310	5		55	310	10		25	90	10
	50	310	4		50	280	7		20	30	20
	45	280	4		45	270	7		15	90	10
	40	260	4		40	270	15				
	35	260	10		35	250	10	**0**	45	280	50
	30	240	3		30	270	15		40	300	14
	25	220	7		25	210	4		35	270	21
	20	230	3		20	180	6		30	270	20
									25	270	20
20	80	40	2	**10**	55	320	13		20	270	20
	75	270	5		50	300	12		15	240	22
	70	310	10		45	310	8		10	290	24
	65	310	6		40	270	13				
	60	320	6		35	270	12				
	55	320	6		30	230	9				
	50	310	6		25	180	3				
	45	280	7		20	90	10				
	40	250	6		15	120	12				
	35	200	6								
	30	230	3								
	25	250	6								
	20	230	5								

* mi/day
1) Spar, J. *Earth, Sea and Air - A Survey of Geophysical Sciences*, Addison-Wesley, Reading, MA 1965

Table 6. Immersed Clo Values Measured During Various Rough Sea Simulation Methods

Compressed Air Methodology	**Air Flow (SCFM)** 3	6	9	12
Diffused	0.15	0.09	0.08	0.08
Concentrated, 23"	0.25	0.22	0.20	0.17
Concentrated, 12"				0.12

Water Pumps Methodology	**Water Flow (GPM)** 150	300	450	600	900
Current	0.19	0.12	0.07		
Spray	0.22	0.10	0.07		
Current & Spray		0.14		0.09	0.08

Wave Maker Methodology	**Mode of Operation** Level 1	Level 2	Level 3	Level 4
Wave Maker	0.09	0.08	0.07	0.05

Vertical Displacement Methodology	**Displacement (times per minute)** 1	2	3	4
Displacement	0.22	0.19	0.17	0.16

Combination Methodology	**Air Flow (SCFM)** 3	6	9	12
Displacement Plus Compressed Air*	0.16	0.16	0.16	0.16

Note: Baseline immersed clo value for Compressed Air, Water Pumps and T-Bar Wave Maker Methodologies was 0.29. Baseline for the remaining methodologies was not comparable due to manikin orientation in the water.

*Vertical displacement at four times per minute plus diffused compresssed air.

Table 7. Summary of Physiological Testing in the NCTRF Hydro-Environmental Tank

Test	Clothing	Air Flow Rate SCFM	Special Conditions	Number of Subjects
NCTRF 1	Coverall	12		8
NCTRF 2	Coverall	13.5		8
NCTRF 3	Coverall	12	Directed Air	4
NCTRF 4	Coverall	12	Directed Air, Arm movement	7
NCTRF 5	Coverall	12	Directed Air, Arm movement	6
NCTRF 6	Float Coat	12	Directed Air, Arm movement	6

APPENDIX B

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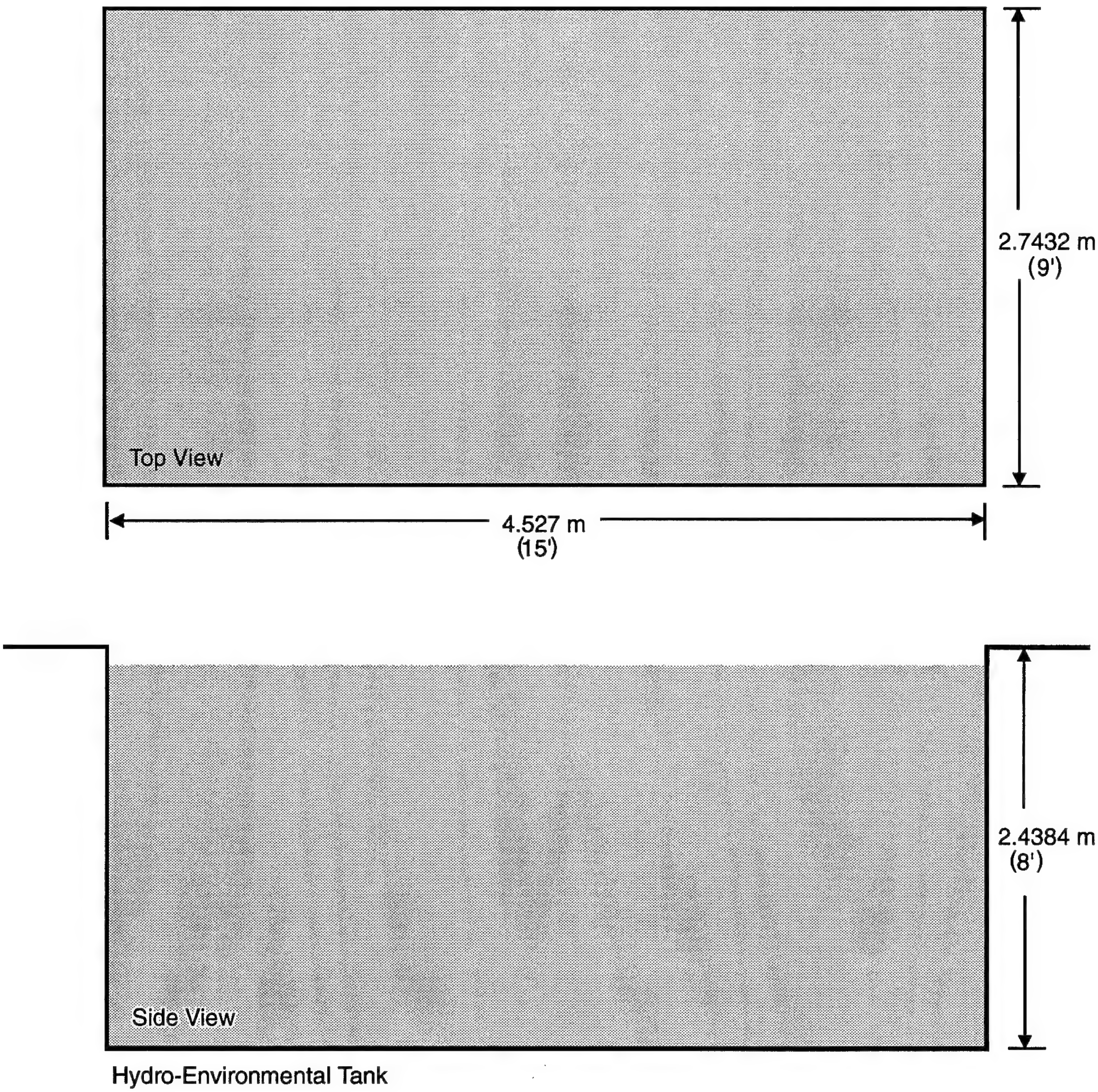

Figure 1. Hydro-Environmental Tank Dimensions

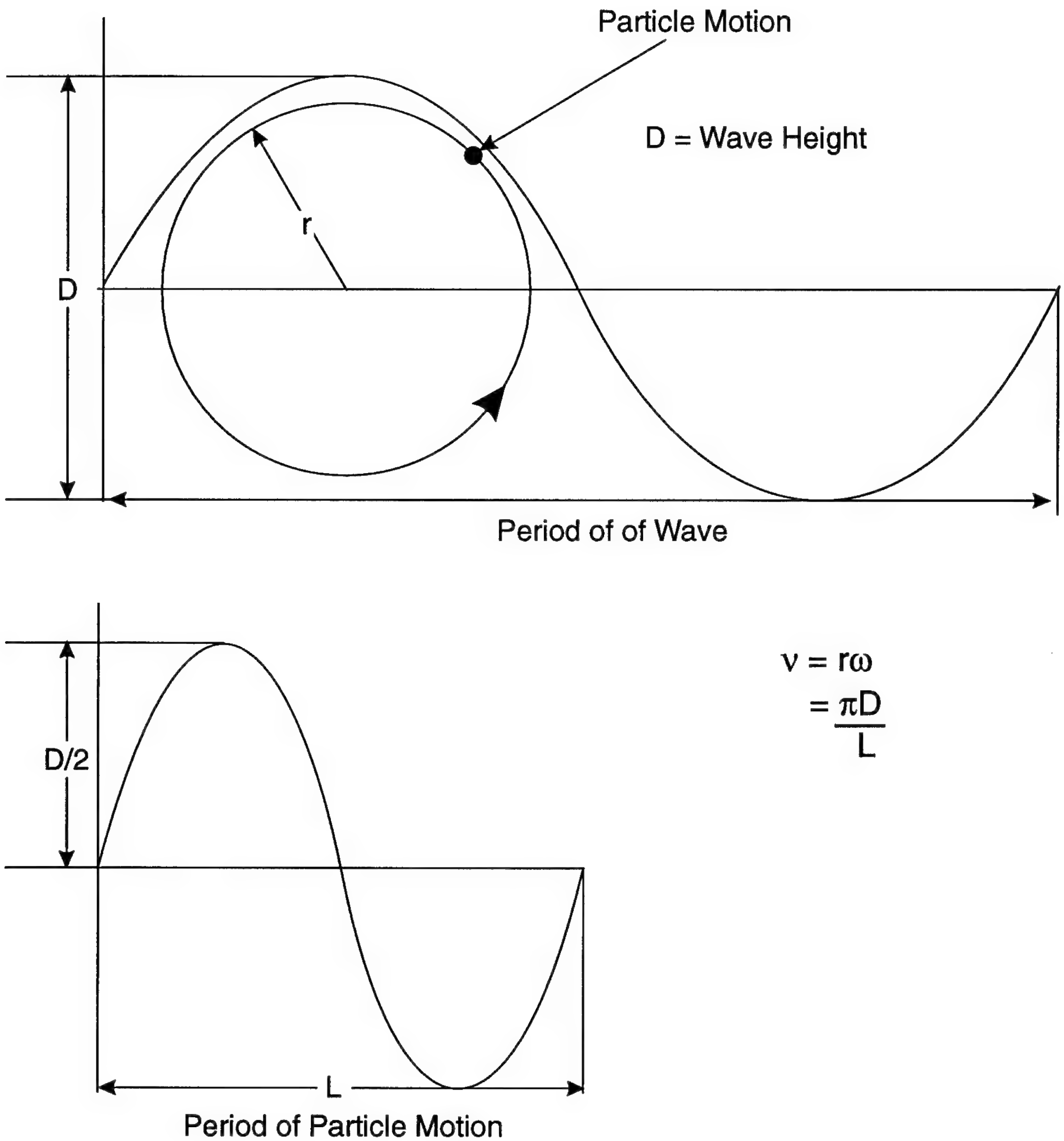

Figure 2. Single Wave Particle Analysis

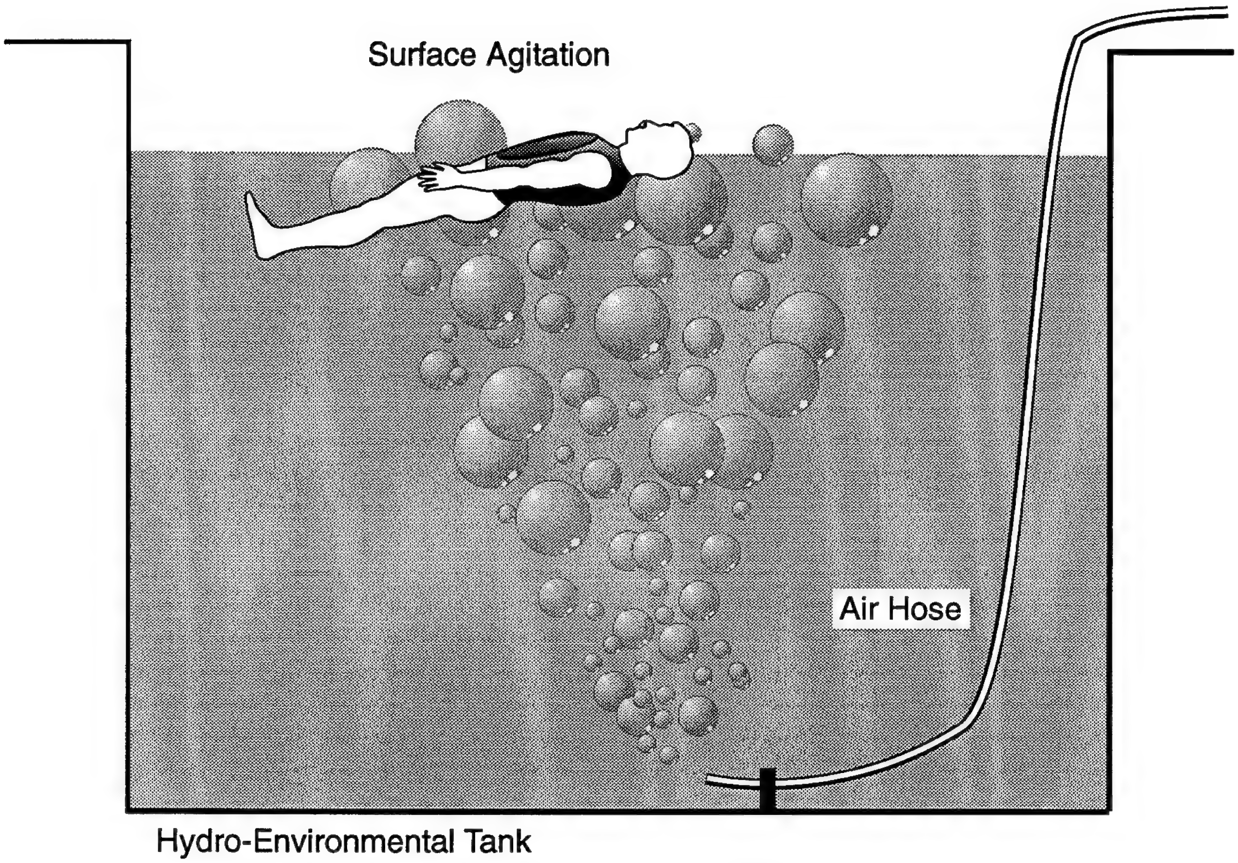

Figure 3. Diffused Compressed Air Methodology

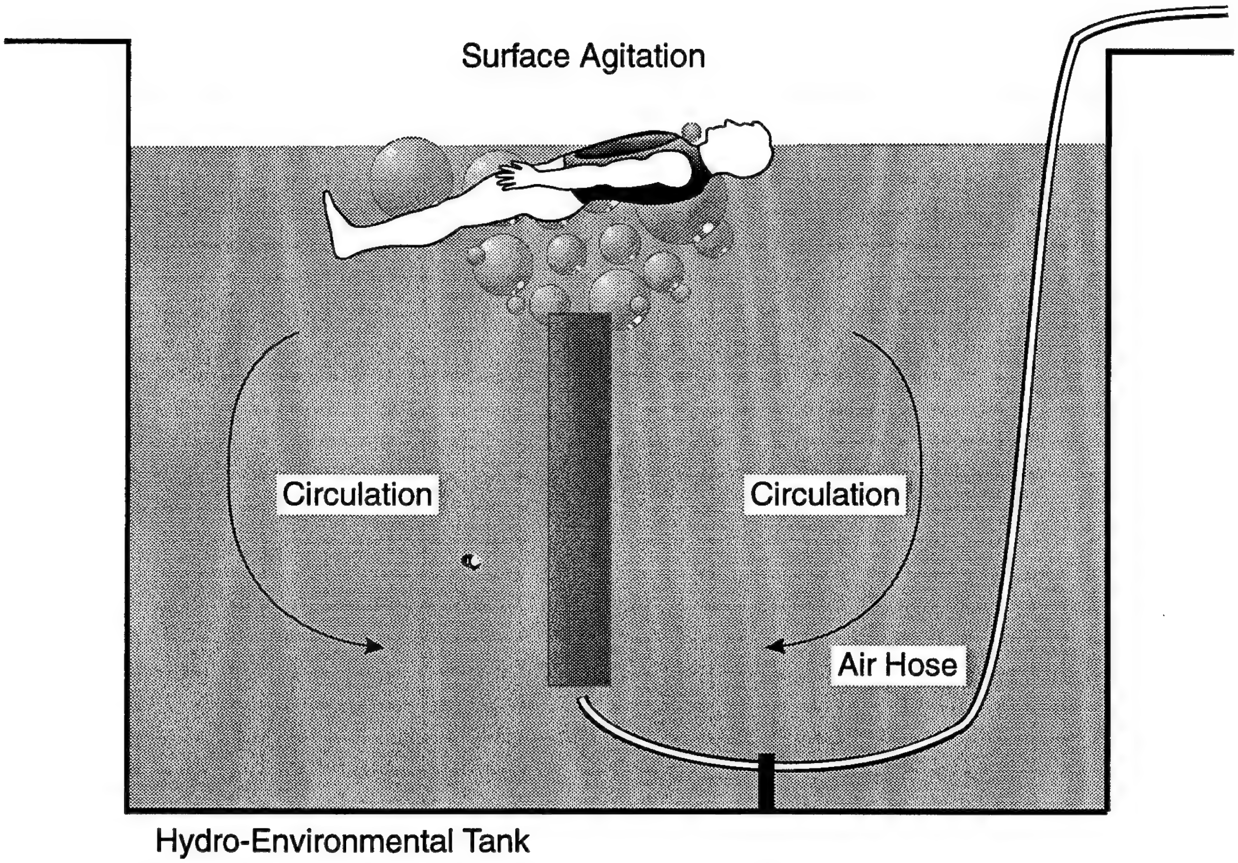

Figure 4. Concentrated Compressed Air Methodology

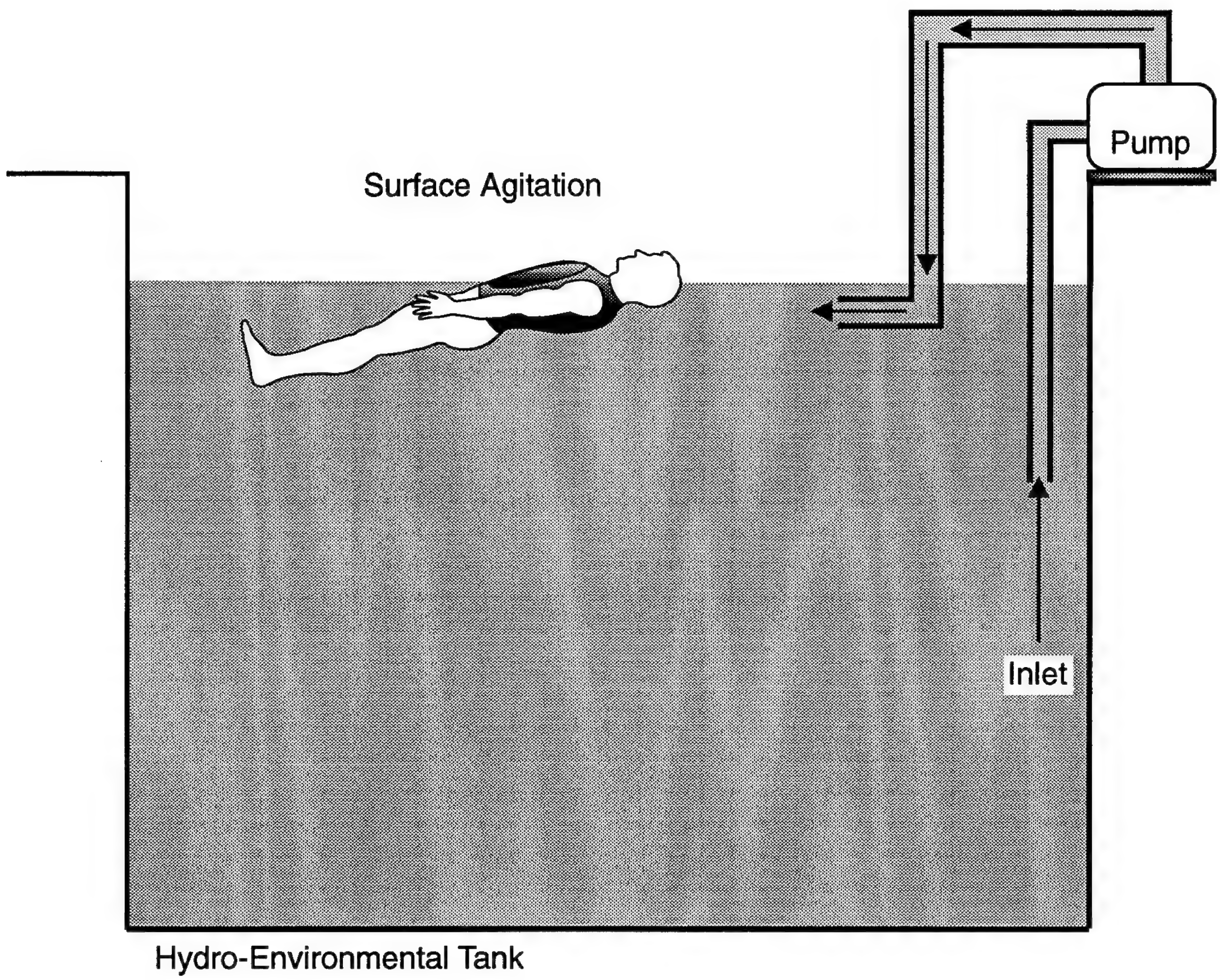

Figure 5. Water Pump, Current Methodology

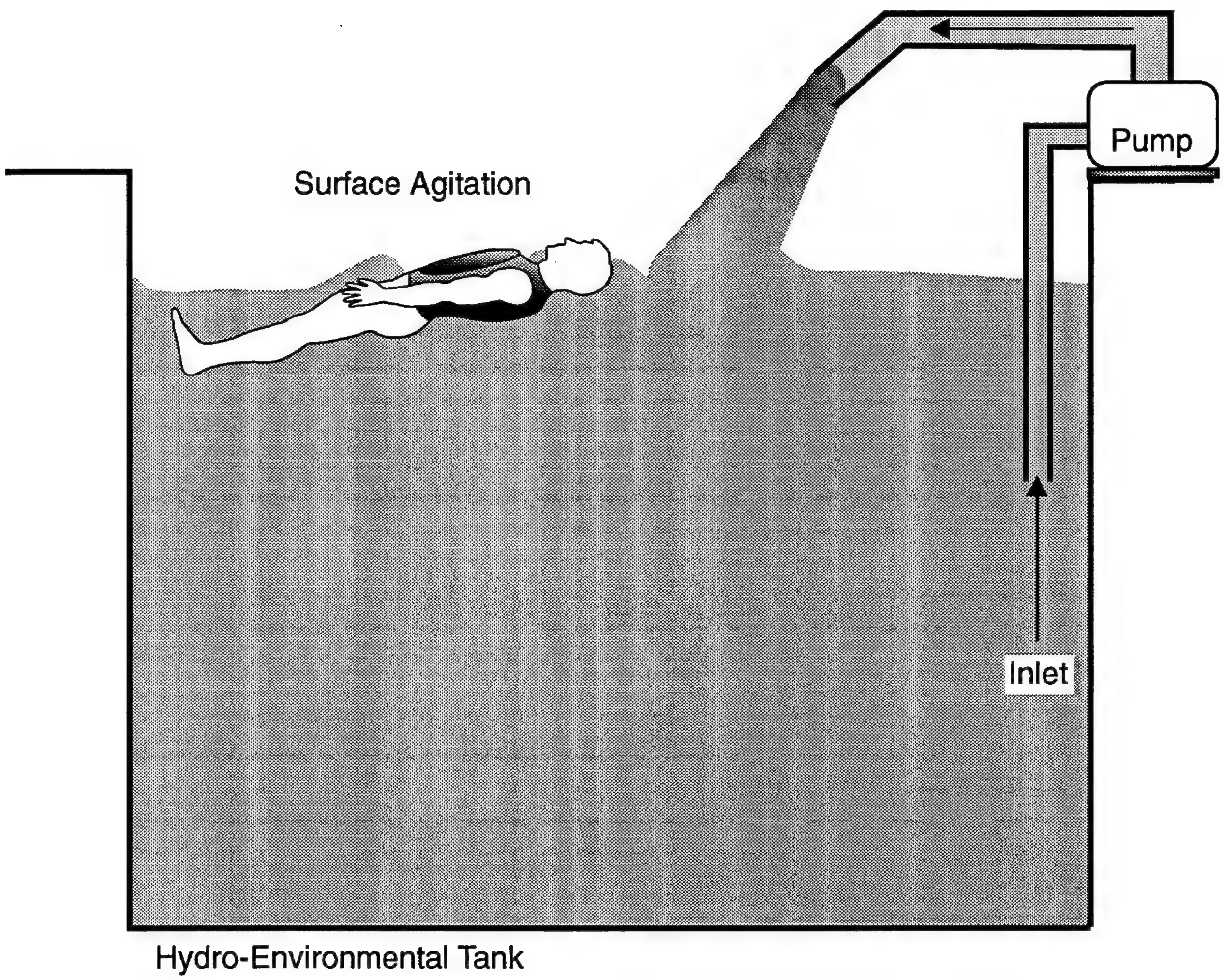

Figure 6. Water Pump, Spray Methodology

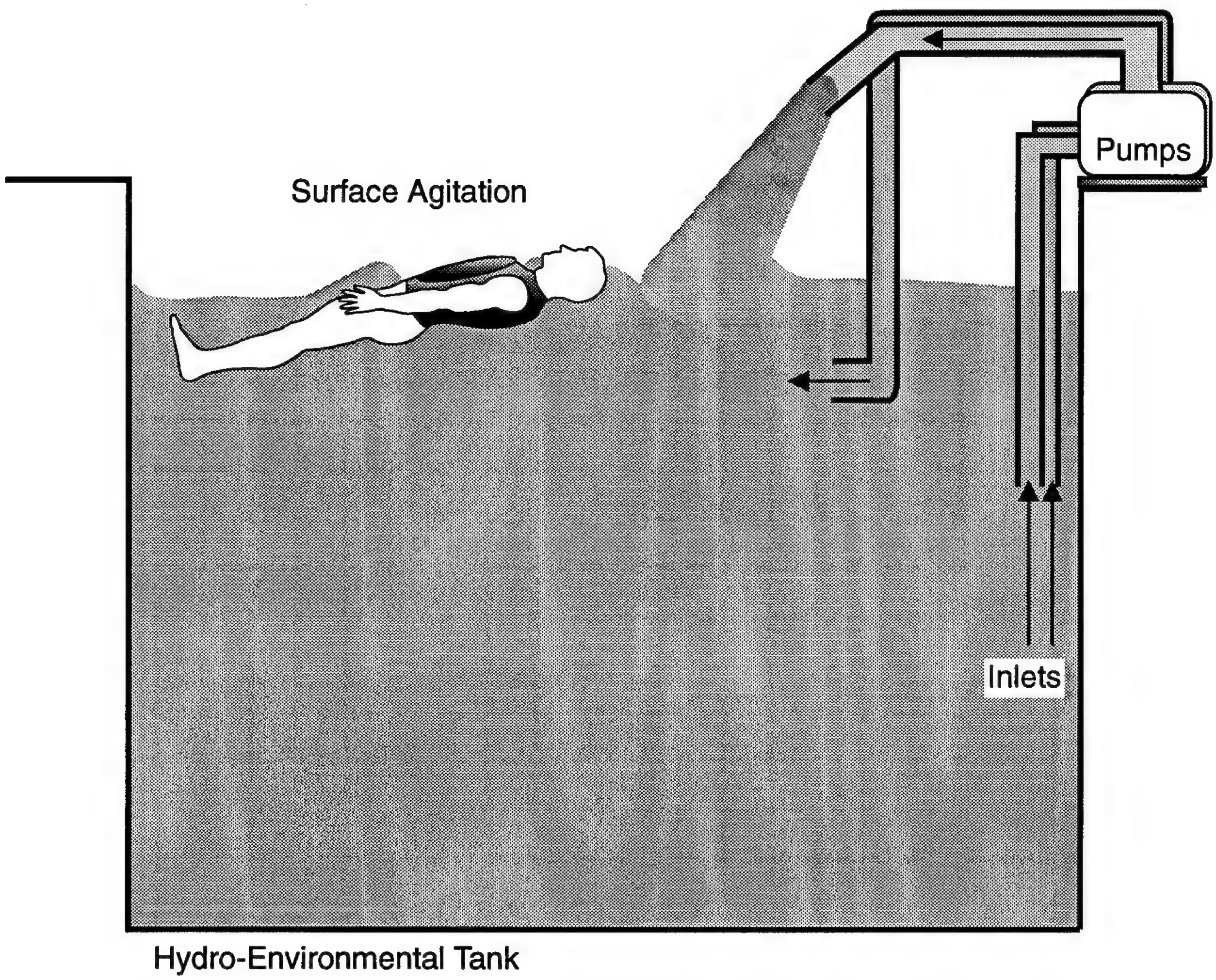

Figure 7. Water Pump Current and Spray Combined Methodology

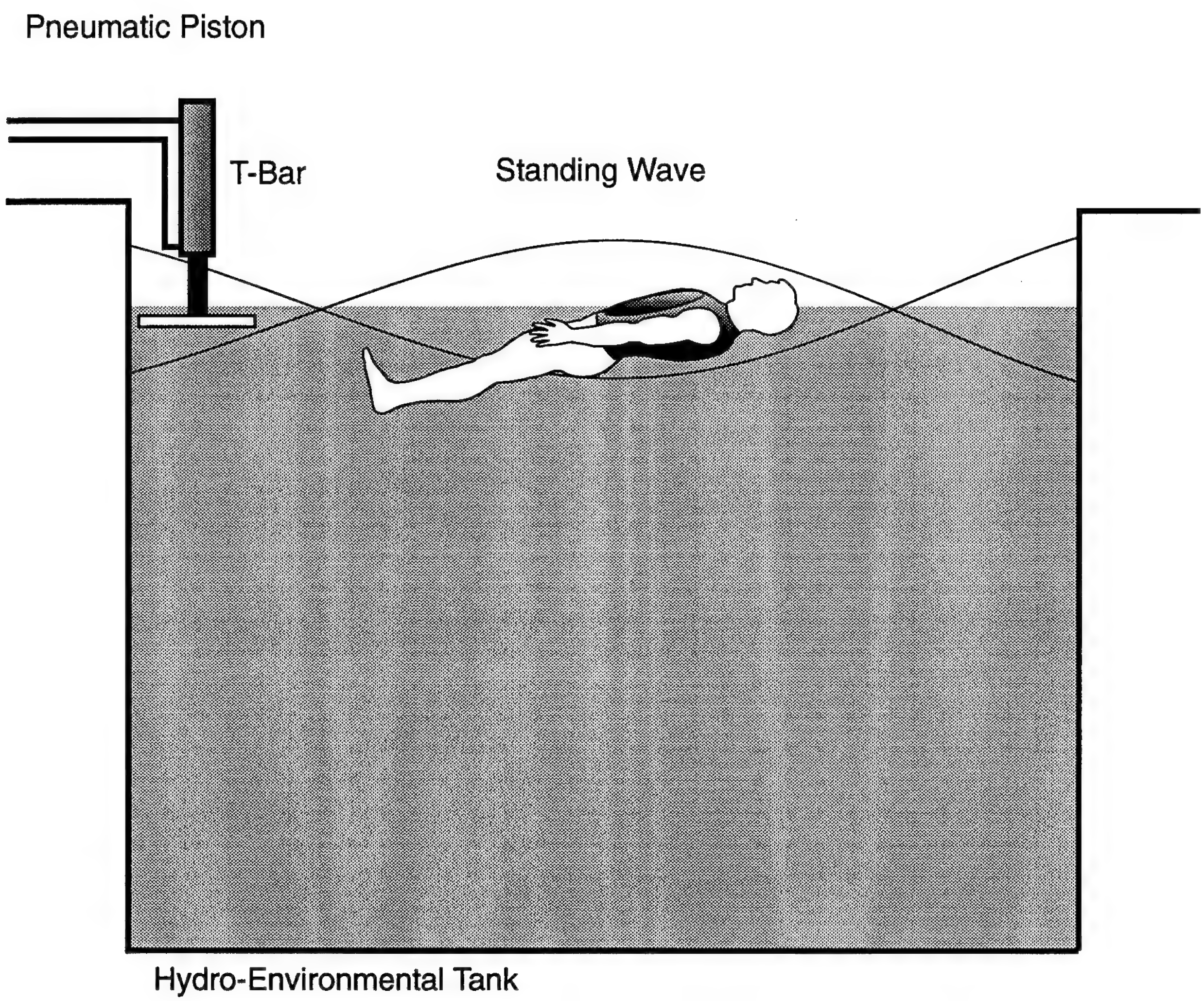

Figure 8. T-Bar Wave Maker Methodology

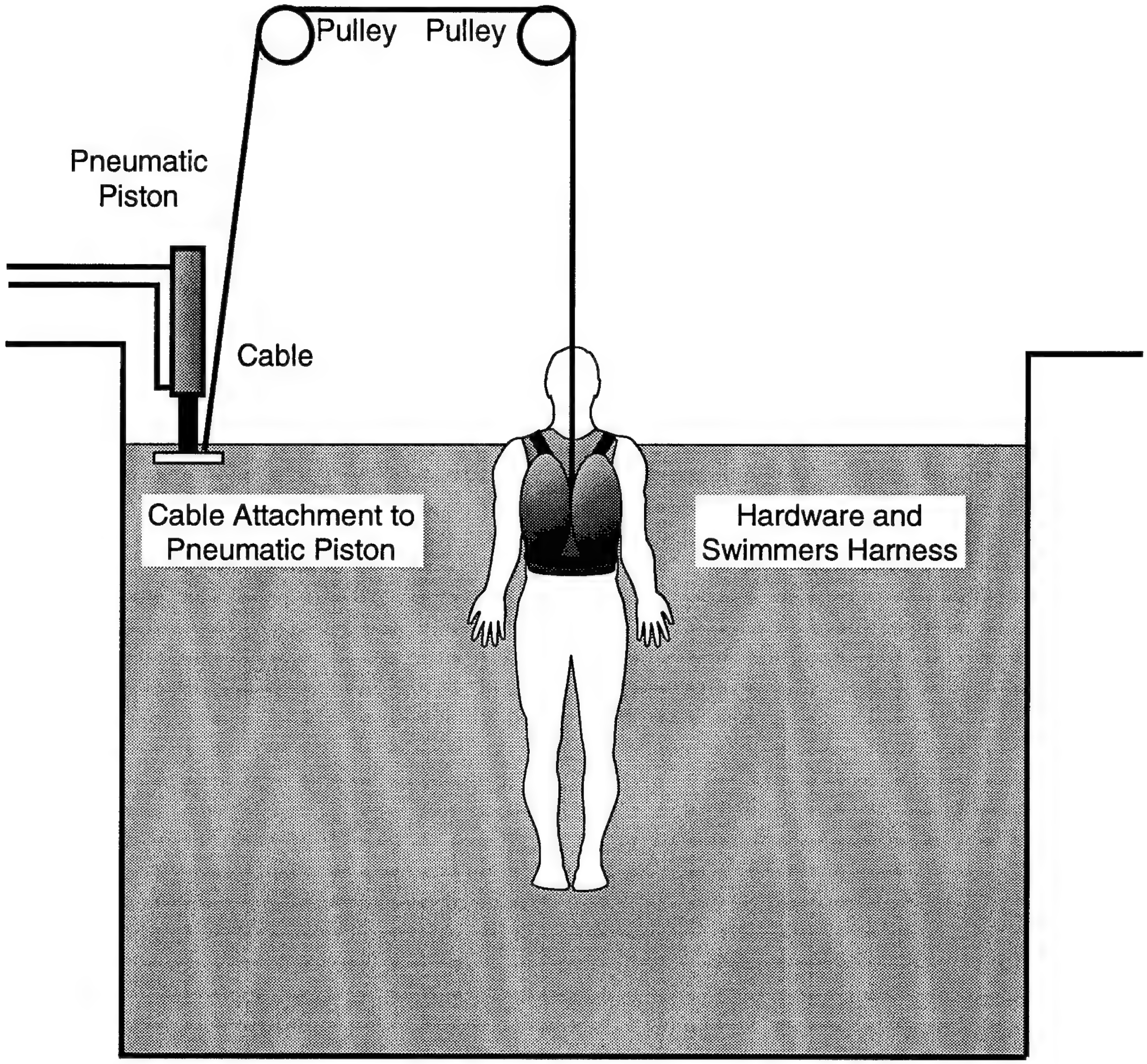

Figure 9. Vertical Displacement Methodology

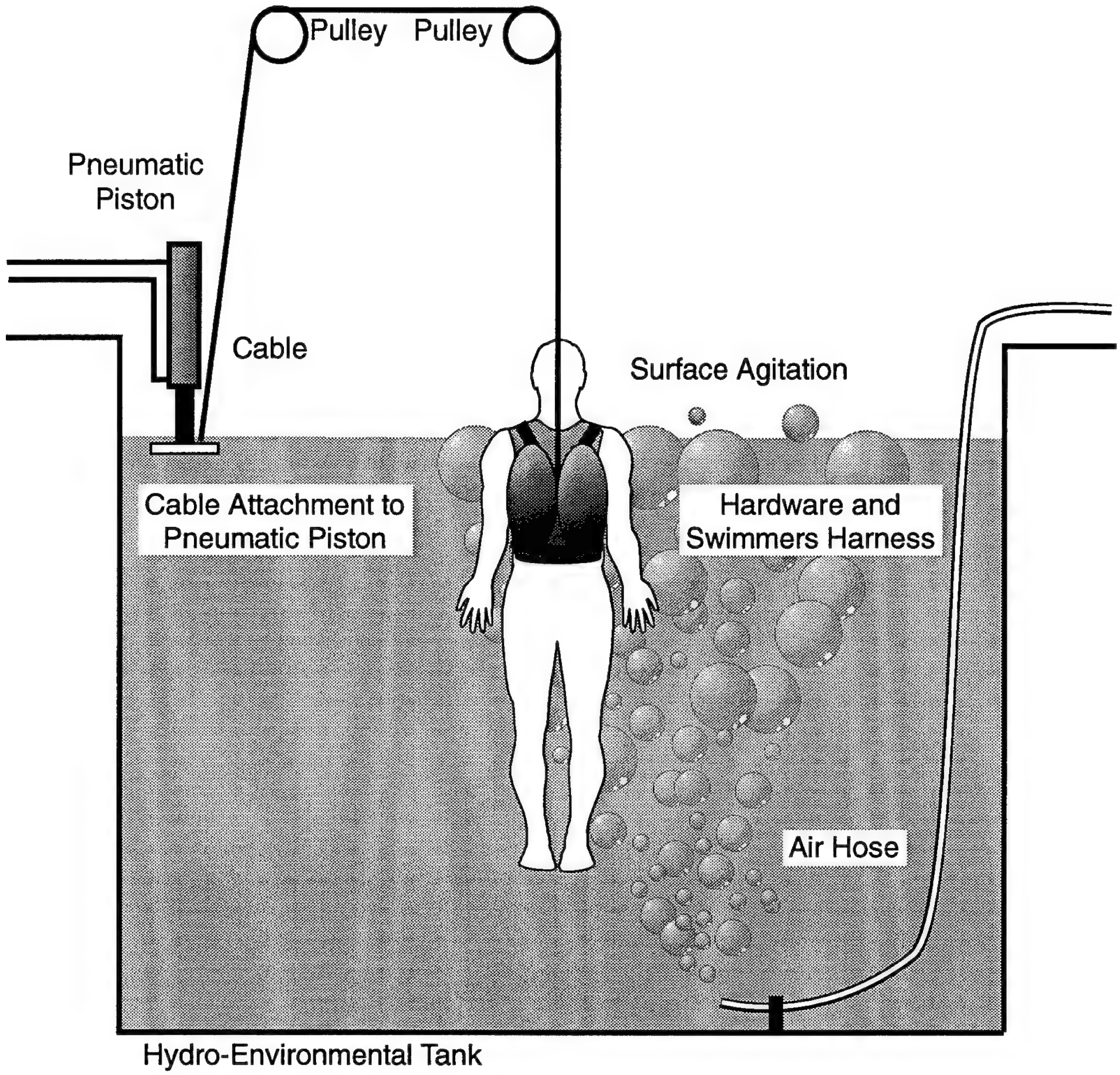

Figure 10. Vertical Displacement Plus Diffused Compressed Air Methodology

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Validation of Rough Sea Simulation Methods for Testing Protective Clothing: Comparison of Field and Laboratory Tests of Body Cooling Rates

Navy Clothing and
Textile Research Facility
Natick, Massachusetts

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13. ABSTRACT *(Maximum 200 words)*

The work reported in this document was undertaken to validate a laboratory rough sea simulation methodology for testing protective clothing. Field testing was conducted with a group of eight Coast Guard volunteers at the U.S. Coast Guard Station, Cape May, NJ (April 1993) with rough seas generated by the wake of a Coast Guard utility vessel. The volunteers' rectal and skin temperature were recorded as a function of immersion time. In tests with three different clothing ensembles, the Coverall plus Shorty Wet Suit provided the highest level of immersion thermal protection, followed by the Coverall alone and the Float Coat. The same group of volunteers participated in tests conducted in the NCTRF hydro-environmental tank using variations of the Diffused Compressed Air Methodology. Five of the six sets of tests were conducted with the Coverall and one test with the Float Coat. In testing with the Coverall, at a compressed air flow rate of 12 scfm, the reduction in the rectal temperature was 2.5 times greater at Cape May than in the NCTRF tank. Although it was possible to obtain rectal cooling rates comparable to ocean testing by using a higher compressed air flow rate (13.5 scfm), some form of respiratory protection would be required to avoid the risk of aspiration with the increased water turbulence.

14. SUBJECT TERMS

Immersion Protection, Rough Sea Simulation Methods, Thermal Manikin Testing, Physiological Testing, Biophysical Testing

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SUMMARY

The main objective of the work reported on in this document was to validate the effectiveness of a laboratory rough sea test method as compared with rough seas generated in the field. A secondary goal was to compare the performance of various types of protective clothing in reducing body heat loss during accidental cold water immersion under rough sea conditions. Heat loss depends on a number of factors, including water temperature, water agitation, the insulative properties of the clothing, body position, and body fat and other physiological characteristics of the individual. For this study, a group of eight Coast Guard volunteers was selected, with a limited variation of physiological characteristics, to provide a homogenous test population.

Field testing was conducted at the U.S. Coast Guard Station, Cape May, NJ. The conditions during the April test were: 10°C water temperature, 10°C ambient air temperature, and 4.5 m/s wind speed. Rough sea conditions, equivalent to a Beaufort Sea State Scale of 4-5, were generated by the wake of a Coast Guard utility vessel. Rectal and skin temperatures of the volunteers were measured with thermistors and recorded with an automatic data collection system. For safety, the volunteers were fitted with a harness which was tethered to a support cable. Each test was ended after 90 minutes, or upon reaching pre-determined temperature criteria or evidence of unusual distress.

Three clothing systems, worn by the military for immersion protection, were evaluated: a foam-insulated Coverall worn over thermal underwear, the same Coverall worn over a Shorty Wet Suit, and a foam-insulated Coat worn over thermal underwear and a standard military work uniform. All clothing systems also included a personal flotation device, foam-insulated mittens, socks, leather boots, and either a foam-insulated surf cap or wool watch cap.

To establish a correlation between field and laboratory testing, the same group of volunteers participated in tests conducted in an environmental water immersion tank at the Navy Clothing and Textile Research Facility (NCTRF) in Natick, MA. During these tests, the volunteers wore the Coverall and the Float Coat clothing systems. Water and air temperature were maintained at 10°C and the wind speed at 4.5 m/s, to duplicate the Cape May conditions. In a previous study of rough sea simulation methods conducted with a Thermal Manikin, it was concluded that water agitation by a diffused release of compressed air was best suited for testing with human volunteers. Therefore, this method was used to create turbulent water. Body heat loss was monitored with the same procedures and equipment used in the field tests. The cooling rate data were statistically analyzed to establish comparisons of clothing protection and to validate the field and laboratory results.

In the field comparison of the three ensembles, the average reduction in rectal temperature was greatest with the Float Coat, second highest with the Coverall alone and least with the Coverall plus Shorty Wet Suit. Back, chest and forearm temperatures were lower with the Float Coat and with the Coverall alone than with the Coverall plus Shorty Wet Suit. Calf and thigh temperatures were

lowest with the Float Coat, and highest with the Coverall alone.

In the laboratory comparison of the Float Coat and the Coverall alone, there were no statistically significant differences in rectal temperature response. When the Coverall was worn, the reduction in rectal temperature, with a compressed air flow rate of 12 scfm, was 2.5 times less than that observed during the field testing at Cape May. By increasing the air flow rate to 13.5 scfm, the reduction in rectal temperature in the laboratory matched that at Cape May. The resulting increase in water turbulence however, produced an unacceptable risk of water aspiration. Other variations of water agitation at 12 scfm, including a more closely directed air stream and arm motion, failed to increase body cooling rate to the desired level.

The results of the Cape May comparison of the three clothing ensembles clearly show the advantage of the Coverall plus Shorty Wet Suit in providing thermal protection from cold water immersion. The differences in the rate of cooling of the various body elements probably reflect the extent to which water flushes through the protective clothing under rough sea conditions. This suggests that the addition of secure closures could increase immersion thermal protection, if the closures did not interfere with the performance of required activities.

The difference in the cooling rates between the field and laboratory tests could also be due to the increased extent of water flushing through the clothing and over the head in the field tests. By using a higher flow rate of compressed air, it is possible to attain cooling rates in the laboratory which are comparable to ocean testing. However, the increased water turbulence poses the risk of aspiration and would require some form of respiratory protection for the volunteers.

I. INTRODUCTION

Accidental water immersion, particularly in rough seas, is a serious problem that threatens all sailors. When immersed in cold water, body heat will be lost despite protective garments. The heat loss depends upon several factors: water temperature; wind speed; insulative properties of the garment; body fat of the immersed individual, and the body position and activity, etc. This heat loss is exacerbated by rough seas, which can flush water around and through the garment.

To examine the effect of rough seas on human thermal responses, the U.S. Coast Guard (USCG) in 1984 conducted a field evaluation on the thermal protection of various USCG operational protective garments when worn in cold water (11°C) under calm and rough sea conditions (1). The study demonstrated that when loosely-fitted, wet-suit garments are worn, body cooling rates were 1.5 to 2.0 times higher in rough seas than in calm seas. The rough seas caused significant flushing of cold water through the garment. This was not the case when tightly-fitted, wet suits or when dry suits were worn. Therefore, these suits appeared to provide better thermal protection in rough seas as well as in calm seas.

The increased body cooling rates in rough seas were also demonstrated in a comparison of the thermal performance of ten different protective garments with human volunteers and a Thermal Manikin. This study was conducted by the Cord Group Limited for the Canadian Defence and Civil Institute of Environmental Medicine (2). It was determined that the drop in thermal protection due to turbulent versus calm water was 29% in human testing and 57% in manikin testing.

The results of the Cord Group study, as well as the 1984 U.S. Coast Guard study, emphasize the importance of conducting water immersion studies in turbulent water to determine the performance of protective garments in the open seas. However, these field evaluations are not always practical or desirable. The field evaluation must contend with the logistics involved in coordinating test volunteers, boats and boat crews, and supporting medical personnel, as well as the uncertainties of the environmental conditions, to assure the safe and successful completion of the evaluation. Therefore, it is desirable to be able to simulate a rough sea environment in the laboratory, in carrying out controlled human and Thermal Manikin studies.

The Navy Clothing and Textile Research Facility (NCTRF) has a Water Immersion Tank in which the water temperature, as well as air temperature, can be tightly controlled. NCTRF previously investigated methods for producing water agitation to simulate rough sea conditions, including the metered release of compressed air, the pumped flow of water and the use of a wave maker (3). The results of this testing, using a Thermal Manikin wearing a foam-insulated Coverall, indicated that significantly increased cooling rates could be achieved by several different approaches for water agitation. However the wave making method was excluded from more extensive testing because, at the time it threatened the integrity of the NCTRF tank. The pumped water method was excluded because the electrical source could not be ground faulted. Accordingly, the use of diffused compressed air to create continuous water turbulence was the method which seemed most

promising for use with human volunteers. Moderate compressed air flow rates could be used to generate water agitation equivalent to a Douglas Sea State Scale of 1 with a 4.5 m/s wind, or level 3 on the Beaufort Sea State Scale (gentle breeze, large wavelets).

The main objective of the work reported here was to validate the effectiveness of the laboratory method of rough sea simulation by making a direct comparison with rough seas generated in the field. A secondary goal was to compare the effectiveness of the immersion thermal protective performance of three clothing systems which are currently used by the military. The field tests were conducted at the U.S. Coast Guard Station at Cape May, NJ, using U.S. Coast Guard test volunteers. The laboratory tests were conducted in the NCTRF environmental tank, using the same group of volunteers. Measured parameters were tolerance time, core (rectal) temperature, and skin temperature at five sites. In addition, the report offers details about the procedures followed for safe and reproducible field and laboratory testing with human volunteers.

II. APPROACH AND BACKGROUND

A. Field Evaluation

1. Physical Characteristics of Volunteers

Eight Coast Guard crewmen were selected for the field evaluation. Each volunteer was interviewed and the nature of the study and the possible risks were explained. The volunteers were screened by a Coast Guard Medical Officer for any previous cold-related injury and for physical fitness. Because percent body fat and body surface area-to-mass ratio largely determine an individual's response to cold water immersion, a homogenous group of volunteers was selected with the required characteristics. The physical characteristics (mean ± standard deviation) of the eight volunteers were: age, 24.6 ± 4.8 years; height, 175.1 ± 3.4 cm; weight, 68.4 ± 5.4 kg, and body surface area, 1.83 ± 0.07 m^2. Body fat, calculated from the sum of four skinfolds, averaged 13.2 ± 1.5% (4). Body fat, determined from hydrostatic weighing, averaged 13.5 ± 2.0 % (5).

2. Test Methods

a) Test Site Conditions

The rough sea field evaluation was conducted in the Cape May inlet at the U.S. Coast Guard Station Cape May, NJ. Testing was conducted at an unused boat house provided by the U.S. Coast Guard Training Center located at Cape May. The environmental conditions measured during the tests were: ambient temperature, 9.2±2.6°C; water temperature, 9.4±1.0°C, and wind speed, 4.5 m/s (10 mph). The April time frame for the field evaluation was planned because of the expected milder ocean temperatures.

b) Method of Rough Sea Generation

Water agitation to create rough sea conditions was generated by the wake of a Coast Guard 41-foot utility vessel. Wave height averaged between 1.2-1.8 m (4-6 feet) and wave frequency averaged 1-1.2 waves per minute. This corresponds to a Beaufort Sea State Scale of 4-5. The sea state created in this manner had been used previously and shown to realistically simulate a rough sea environment (1).

c) Data Collection

1) Data Collection System

The computerized data collection system consisted of the following components: personal scientific computer; dual 3.5" flexible disk drive; signal scanner; digital volt meter; eight-pen plotter, and impact printer. An electrical safety check was made of the data acquisition equipment and electrical supply, by Cape May biomedical personnel, prior to conducting the field evaluation.

2) Temperature Measurement

Skin temperatures were measured at five sites: chest; back; forearm; medial thigh, and calf. The temperatures were measured with surface temperature thermistors. Rectal temperature was measured with a thermistor inserted approximately 10 cm beyond the anal sphincter.

3) Connection Between Test Volunteers and Data Collection System

The skin and rectal temperature thermistors were hardwired into a waterproof harness, approximately 1.8 m in length. The harness terminated at a waterproof, multi-pin connector. Each volunteer was assigned his own harness, which coupled with waterproof connectors to a 30-m length of waterproof cable. In turn, the 30-m cable was connected to the computerized data acquisition system, which was located in the boat house.

A length of polypropylene cable was suspended between the boat house and a pylon located approximately 6 m away. The waterproof cable was tethered to this support cable which could be adjusted to accommodate the tides. Also tethered to the length of support cable were four safety tethers with hardware to attach to the swimmer's harness. This insured the safety of each volunteer, by preventing him from being washed away by the wave action.

d) Testing Procedures

1) Testing Routine

Testing was performed twice a day. The volunteers were split into two groups: morning and afternoon. The morning group reported at 0700 hours and the afternoon group reported at 1300 hours. Each volunteer was instrumented with his temperature harness, which was checked for proper operation prior to donning the protective clothing. Once dressed, the volunteers entered a 12-foot Rigid Hull Inflatable (RHI) rescue boat that transported them to the test site at the other side of the boat house.

At the test site, each volunteer's swimming harness was attached to the safety tether. The instrumentation harness was connected to the waterproof cable. Once all volunteers were connected to the data acquisition system, data collection began. Immediately after the data for time zero had been collected, the volunteers entered the water and assumed a cold water survival position (arms crossed, knees drawn up). As soon as the volunteers entered the water and the RHI rescue boat was clear, the Coast Guard 41-foot boat began generating the waves.

Data were collected every 20 seconds. At the end of 2 minutes the data were averaged, printed and plotted. Data were also saved on a disk every 10 minutes, which prevented any excessive loss of data in case of power failure.

2) Criteria For Termination of Test/Safety Procedures

A volunteer's exposure was terminated for any of the following reasons: completion of the 90-min exposure; rectal temperature reached 35°C; skin temperature at any site reached 4.4°C; the volunteer showed signs or symptoms of impending cold injury, or unusual distress; the Medical Officer requested termination, or the volunteer requested voluntary termination.

The following safety procedures were used during all of the field tests: each volunteer wore a swimmer's harness which was tethered to the cable suspended between the boat house and pylon; a rescue boat, operated by an experienced coxswain and at least one crew member stationed in close proximity at all times; a Medical Officer on the rescue boat or in the water at all times; medical life support personnel and equipment available in the boat house and within 0.8 km of the field test site, and a hot water (38°C) shower available at the rewarming site. In addition, all test volunteers were experienced swimmers.

3. Clothing Systems

a) Overview

Three protective clothing systems were evaluated in the field tests: a) Coverall; b) Coverall plus Shorty Wet Suit; and c) Float Coat. Most of the components of the clothing systems were provided by the U.S. Coast Guard. The Coverall was similar to that used during the previous Thermal Manikin, laboratory evaluation of various rough sea simulation methods. The only differences were external (pockets and straps).

The protective clothing systems are described below, and illustrated schematically in Figures 1-3.

b) Coverall (Figure 1): One-piece coverall (used by U.S. military aircrew personnel) consisting of an aramid fire-retardant outer and inner shell with foam insulation (3 mm PVC), worn over gym shorts and cotton long underwear (shirt and drawers); wool/cotton socks; leather work boots; diver's, three-fingered mittens (3 mm Neoprene); surf cap (3 mm Neoprene); life preserver unit (LPU-26/P); and swimmer's harness.

c) Coverall Plus Shorty Wet Suit (Figure 2): Coverall as described above, worn over gym shorts and a custom-fitted Lycra® covered Shorty Wet Suit with foam insulation (3 mm); wool/cotton socks; leather work boots; diver's three-fingered mittens (3mm Neoprene); surf cap (3 mm Neoprene); life preserver unit (LPU-26/P); and swimmer's harness.

d) Float Coat (Figure 3): Float Coat (jacket with crotch closure flap),consisting of Nylon iner and outer shell with foam-insulation (3 mm Ensolite®), worn over gym shorts, cotton long underwear (shirt and drawers), and a standard U.S. military work uniform (chambray shirt with denim trousers); wool/cotton socks; leather work boots; diver's three-fingered mittens (3 mm Neoprene); wool watch cap; and swimmer's harness.

B. Laboratory Evaluation

1. Physical Characteristics of Volunteers

The same eight U.S. Coast Guard Crewmen who participated in the field evaluation traveled to Natick, MA to participate in the laboratory evaluation.

2. Test Methods

a) Methods of Rough Sea Simulation

The laboratory evaluation was conducted at NCTRF's Water Immersion Laboratory in Natick,

MA. The Immersion Laboratory tank measures 6.7 meters long, 4.3 meters wide, 2.6 meters high (22x14x8.5 feet) and is described in detail in a related report (3).

Water agitation during the laboratory evaluation was provided by a compressed air method. Continuous water turbulence was created by releasing controlled volumes of compressed air from an air line secured to the bottom of the tank. As the air rose, it expanded and created water agitation over a wide area. The observed water agitation, with an air flow rate of 12 scfm, took the form of waves, 0.3-0.4 m in height, that dissipated and canceled at the tank walls. This wave action corresponds to a Beaufort Sea State Scale of 2 and was previously shown to be effective in reducing immersed clo value by 72% on a thermal manikin wearing the Coverall. Although a Beaufort Sea State Scale of 4-5 was created during the field test, waves of this size are not possible in the NCTRF hydro-environmental tank or in most other temperature-controlled immersion tanks. The present evaluation attempted to determine whether comparable body cooling rates could be achieved using conditions equivalent to a lesser Sea State.

The dimensions of the NCTRF hydro-environmental tank limited the testing to two volunteers tested at the same time. During the previous manikin evaluation, one air compressor was used. A second air compressor was added during the laboratory evaluation in order to provide water agitation to both test volunteers. The compressors were located in a machinery space just outside the test chamber. The compressed air was piped to an area just beneath the test chamber. The air was metered and directed to the tank floor where it was released. Metering the compressed air provided an even and continuous distribution of water agitation.

b) Data Collection

1) Data Collection System

Data collection for the laboratory evaluation used the same computerized data acquisition system that was used in the field. An electrical safety check was conducted by the Biomedical Maintenance Group of the U.S. Army Research Institute of Environmental Medicine, located at Natick.

2) Temperature Measurement

The same instrumentation used in the field evaluation was used to monitor skin and rectal temperatures in the laboratory.

3) Connection Between Test Volunteers and Data Collection System

The waterproof cable connecting the data acquisition system to the instrumentation harness worn by the test volunteer was fed into the tank chamber through a small opening in the chamber floor and was secured to the railing surrounding the tank.

c) Testing Procedures

1) Testing Routine

Testing was performed four times per day using two volunteers at the same time. The volunteers were divided into four groups which were asked to report at different times during the day, between 0700 and 1430 hours. Each volunteer was fitted with his instrumentation harness, which was checked for proper operation prior to dressing in the protective clothing. Once dressed, the volunteers walked upstairs to the test chamber where the tank is located. They were then connected to the waterproof data acquisition cable.

When both volunteers were connected, the data collection began. Following acquisition of the zero time data, the volunteers entered the tank; the swimmer's harness was connected to a safety tether, and the volunteers assumed the survival position. As soon as this was completed, valves were opened to begin the continuous water agitation. A variable speed fan was used to supply a constant wind directed across the water surface and measuring 4.5 m/s at the location of the test volunteers. Water and air temperature were both maintained at 10°C, duplicating the Cape May conditions.

Data were collected every 20 seconds. At the end of 2 minutes, data were averaged, printed and plotted. Data were also saved to a disk every 10 minutes to prevent any excessive loss of data in case of a power failure.

2) Criteria for Termination of Test/Safety Procedures

The same termination criteria used for the field testing were used in the laboratory. In the immersion tank, each volunteer's swimmer's harness was tethered to a cable suspended across the width of the immersion tank. Two technicians were in the test chamber and a Medical Officer was present at all times. Medical life support personnel and equipment were available within 0.8 km of the laboratory. A hot water shower was available in the laboratory.

3. Clothing Systems

Two of the three clothing ensembles evaluated in the field test - the Coverall alone, and the Float Coat - were used in the laboratory test.

III. RESULTS

A. Tests Performed

During the field evaluation, each volunteer participated in a total of three water immersions, wearing each of three different clothing ensembles (Coverall, Coverall plus Shorty Wet Suit, and Float Coat). Due to a time restraint and human use protocol restrictions, the number of test conditions in the laboratory at NCTRF was limited to six. With the exceptions explained below, most of the volunteers participated in a total of six immersions in the laboratory.

Because the purpose of the tests at the NCTRF laboratory was to validate results of the field evaluation at Cape May, the data from each test were examined at the end of each day. If the laboratory data did not compare well with the field data, a modification was made to the rough sea method. The six laboratory tests are listed in Table 1.

The first test, NCTRF 1, used the same water agitation method as in the previous thermal manikin evaluation. Because this resulted in slower body cooling rates than Cape May, in NCTRF 2, the water was made more turbulent by increasing the amount of compressed air. This resulted in cooling rates that agreed well with the field data. However, the increased water turbulence caused an unacceptable risk of water aspiration. Accordingly, for NCTRF 3, the air pressure was lowered to the original level, but the air was directed closer to the volunteers. This modification did not increase the cooling rate to the desired level and it was terminated after four volunteers were tested.

In an attempt to increase flushing of water through the garment, and thereby, increase heat loss, the volunteers were instructed to submerse their arms once every 60 seconds for NCTRF 4. Because of illness, one volunteer did not participate in this test condition. Again, this change did not result in the desired cooling rate. Nonetheless, in order to test reproducibility of the rough sea method, this test was repeated for NCTRF 5. Due to illness, two volunteers did not participate in this test.

On the last test day (NCTRF 6), the Float Coat rather than the Coverall was worn. The rough sea method was the same as used for NCTRF 4 and 5. Due to illness, two volunteers did not participate in the test of the Float Coat.

B. Statistical Analysis of Temperature Data

The rectal and skin temperature data were analyzed using two-way (garment or test day X time) repeated measures analyses of variance (ANOVA). Data points measured every 10 minutes were used. The following analyses were carried out:

a. Coverall vs. Coverall plus Shorty Wet Suit vs. Float Coat (Cape May)
b. Coverall vs. Coverall plus Shorty Wet Suit (Cape May)
c. Coverall (NCTRF 1) vs. Float Coat (NCTRF 6)

d. Coverall (NCTRF 4) vs. Coverall (NCTRF 5)
e Float Coat (Cape May) vs. Float Coat (NCTRF 6)
f. Coverall (Cape May) vs. Coverall (NCTRF 1, NCTRF 2) (eight volunteers)
g. Coverall (Cape May) vs. Coverall (NCTRF 1, NCTRF 2, NCTRF 4) (seven volunteers)
h. Coverall (Cape May) vs. Coverall (NCTRF 1, NCTRF 2, NCTRF 4, NCTRF 5) (six volunteers)

Because only four volunteers participated in NCTRF 3, that test was not included in any statistical analysis. Because of early terminations, statistics were performed on the data for differing test durations corresponding to the above test conditions as follows: up to 50 minutes (a); 60 minutes (e); 80 minutes (b, f, g, h), and 90 minutes (c, d). Within these times, missing values due to volunteer attrition were estimated using least squares, and the degrees of freedom were adjusted accordingly. Tukey's test was used to locate the significant differences. Significance was accepted at the 0.05 level.

C. Field Comparison of Garments (Analyses a and b)

In all tests, maximal exposure time was limited to 90 minutes. In approximately one-third of the immersions, volunteers were not able to complete the 90-minute exposures. Of the early terminations, approximately 60% of the volunteers reached the rectal temperature limit of 35°C. Some volunteers were removed from the water at the discretion of the Medical Officer because their rectal temperature dropped to within 0.5°C of this limit. This decision was made because of the longer time required to remove the volunteer from the water and reach the rewarming facility in the field (compared to the laboratory), and because of the significant afterdrop in core temperature due to the test conditions. Of the remaining early terminations, three were due to severe leg and abdominal cramps, two were due to water aspiration, one was due to a severe earache, and three were due to more subjective reports of "cold, nausea and pain".

When the Coverall alone was worn, five of the eight volunteers were able to complete the exposure, with an average exposure time of 86 minutes. When the Coverall was worn with the Shorty Wet Suit, all but one volunteer were able to complete the 90 minutes, with an average exposure time of 85 minutes. When the Float Coat was worn, none of the volunteers were able to complete 90 minutes. Exposure time ranged from 32 to 62 minutes and averaged 49 minutes.

The average change in rectal temperature as a function of immersion time with each of the three ensembles is shown in Figure 4. From 20 minutes on, the reduction in rectal temperature was greater with the Float Coat and with the Coverall alone, than with the Coverall and Shorty Wet Suit ($p<0.05$). From 40 minutes on, the reduction in rectal temperature with the Float Coat was also greater than with the Coverall alone. After 50 minutes of water immersion, the change in rectal temperature averaged -0.6, -1.3 and -1.9°C with the Coverall plus the Shorty Wet Suit, Coverall alone, and Float Coat, respectively.

Calf temperature was significantly lower at all time periods when the Float Coat was worn, than when the Coverall alone was worn ($p<0.05$). After 50 minutes of immersion, calf temperature averaged 12.9, 18.3 and 21.7°C with the Float Coat, Coverall plus Shorty Wet Suit, and Coverall alone, respectively.

Back, chest and forearm temperatures were significantly lower at all times with the Float Coat and with the Coverall alone, than with the Coverall plus Shorty Wet Suit. Within 30 minutes, these temperatures were lower with the Float Coat than with the Coverall alone ($p<0.05$). After 50 minutes of immersion, back, chest and forearm skin temperatures with the Float Coat were approximately 6.0°C lower than with the Coverall alone, and approximately 10.0°C lower than with the Coverall plus Shorty Wet Suit.

Thigh temperature with the Float Coat was also significantly lower at all times, than with the Coverall and Coverall plus Shorty Wet Suit. Thigh temperature with the Coverall plus Shorty Wet Suit was lower than with the Coverall alone ($p<0.05$). Thigh temperature at 50 minutes averaged 11.3, 15.2 and 19.7°C with the Float Coat, Coverall plus Shorty Wet Suit, and Coverall alone, respectively.

D. Laboratory Tests (Analyses c and d)

When the Coverall alone was worn, average exposure times were 79 minutes for NCTRF 2, 87 minutes for NCTRF 4, and 88 minutes for NCTRF 1, 3 and 5. In NCTRF 1, 3, 4 and 5, all but one of the volunteers were able to complete 90 minutes. In NCTRF 2, only three of the eight volunteers completed 90 minutes. When the Float Coat was tested (NCTRF 6), exposure time averaged 87 minutes. Only one volunteer was unable to complete the exposure.

Figure 5 illustrates rectal temperature responses when the two different clothing systems, the Coverall and Float Coat were tested (NCTRF 4 and 6). There were no statistically significant differences between the two clothing systems ($p = 0.06$). After 90 minutes, the change in rectal temperature averaged -1.3°C with the Coverall and -1.7°C with the Float Coat. There were no significant differences between the two ensembles in back, chest, or calf skin temperatures ($p>0.05$). At 90 minutes only, forearm temperature was lower with the Coverall than with the Float Coat, by an average of 4.6°C. At all times, the medial thigh temperature was lower with the Float Coat than with the Coverall, by an average of 9.2°C.

When repeatability was evaluated with the Coverall during NCTRF 4 and 5, there were no significant differences in rectal temperature response ($p>0.05$) (see Figure 6). There were also no significant differences in any of the measured skin temperatures between the two tests.

E. Comparison of Field and Laboratory Data (Analyses e, f, g and h)

Two of the clothing ensembles, the Float Coat and the Coverall alone, were evaluated both in the

field at Cape May and in the laboratory at NCTRF. Figure 7 presents rectal temperature responses when the Float Coat was worn at both locations. From 30 minutes on, the decrease in rectal temperature with the Float Coat in the field was significantly greater than in the laboratory ($p<0.05$). After 60 minutes of immersion, the change in temperature averaged -1.1 and -2.6°C for the laboratory and field tests, respectively. There were no significant differences in calf, chest, or forearm skin temperatures between the two locations. Thigh temperature, however, was lower by an average of 3.3°C at all times during field compared with laboratory testing ($p<0.05$). From 30 minutes on, back temperature was also significantly lower during field testing, by an average of 2.4°C.

The Coverall alone was worn once at Cape May, and during NCTRF 1, 2, 4 and 5. Figure 8 illustrates changes in rectal temperature during these tests. There were no significant differences in the rectal temperature responses between Cape May and NCTRF 2 ($p>0.05$). After elapsed times of 30 to 40 minutes, the decreases in rectal temperature at Cape May and NCTRF 2 were significantly greater than NCTRF 1, 4 or 5. The change in rectal temperature after 80 minutes averaged -0.8, -1.0, -1.2, -1.9 and -2.0°C with NCTRF 5, 1, 4, Cape May, and NCTRF 2, respectively.

No consistent pattern emerged for the temperature responses at the other body monitoring sites. There were no significant differences in chest or calf skin temperatures between Cape May and NCTRF 1, 2, 4 and 5 ($p>0.05$). At most immersion times, there were no differences in back temperatures. Thigh temperatures at Cape May and NCTRF 2 were significantly lower than NCTRF 1, 4 and 5 at all times, by an average of 4.0°C. By 30 minutes, forearm temperatures measured at Cape May and NCTRF 2, 4 and 5 were significantly lower than NCTRF 1. At 80 minutes, forearm temperatures averaged 17.6 (NCTRF 2), 19.8 (NCTRF 4), 22.3 (NCTRF 5), 23.9 (Cape May) and 28.4°C (NCTRF 1).

IV. CONCLUSIONS

Of the three clothing ensembles tested in this evaluation, the Coverall plus Shorty Wet Suit provided the highest level of thermal protection. The Coverall alone was second best and the Float Coat provided the least amount of thermal protection. During the field testing conducted at Cape May, body cooling rate was three times as high when the Float Coat was worn compared to the Coverall with Shorty Wet Suit combination. Significant differences in skin temperatures at various sites and with the various clothing ensembles were probably largely due to differences in the extent of the water flushing through the garments. This suggests that improved thermal protection might be achieved with tighter closures at locations such as the neck, wrists and ankles, if this design change could be accomplished without impairing the performance of required activities.

With one exception, the various compressed air methods used in the laboratory to simulate realistic rough sea conditions resulted in smaller cooling rates than those obtained during field testing. The one laboratory method that did result in the desired cooling rate, by increasing the flow rate of

compressed air, caused an unacceptable risk of water aspiration for routine use with human volunteers. (In the present evaluation, the test volunteers were Coast Guard crewman who were experienced swimmers.) The differences between the laboratory and the field data may have been due to a greater degree of water flushing through the garments and over the head during the field test. It remains to be determined if there are other modifications of the compressed air method which can overcome the differences from the field testing without causing an unacceptable risk of water aspiration. Alternately, the risk of water aspiration with the increased turbulence produced by a higher compressed air flow rate might be adequately reduced with some sort of respiratory protection.

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Comparison of Field and Laboratory Tests of Body Cooling Rates Using a Wave Maker To Simulate Rough Seas

Navy Clothing and
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13. ABSTRACT (Maximum 200 words)

The Navy Clothing and Textile Research Facility (NCTRF) has conducted studies of rough sea simulation methods for the reliable testing of immersion protective clothing with volunteer subjects in the laboratory. All comparison tests have used the coverall, a wet-suit design which allows water to flush through the garment. In a prior study, variations of a Compressed Air Method of water agitation were used in the NCTRF hydro-environmental tank. At an air flow rate of 12 scfm, body cooling rates were only one-half that measured under comparable conditions in ocean tests at the Coast Guard Station, Cape May, NJ (water and air temperature 10°C; wind speed 4.5m/s). Although higher cooling rates could be achieved by increasing the air flow rate, this produced an unacceptable risk of aspiration. The current report deals with tests conducted with a wave maker, a large piston-driven paddle which generates a standing wave with a peak height of up to 0.46 meters at 1.4 second intervals. Eight volunteers were selected to match the physical characteristics of the earlier test group. Data included rectal temperature, skin temperature and heat loss. The first wave maker trial produced body cooling rates which duplicated the field results at Cape May. However, cooling rates were much less in the two subsequent trials. This difference is attributed to a "learning effect". As a result, volunteers adjusted their posture to reduce the extent of water flushing through the garment. Nonetheless, the wave maker is considered to be the most promising current approach for rough sea simulation.

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SUMMARY

The accidental water immersion of sailors is a life-threatening problem, particularly in rough seas, since body heat will be lost despite the use of protective garments. A previous study by the U.S. Coast Guard demonstrated the effect of wave action on human thermal responses to cold water immersion (1). When loosely-fitted, wet-suit garments were worn, body cooling rates were 1.5 to 2.0 times higher in rough than in calm seas. This was attributed principally to significant flushing of cold water through the garment. Accordingly, a useful laboratory method for immersion testing of protective clothing systems with human subjects requires the development of a suitable method of water agitation to produce the accelerated body cooling rate caused by rough seas.

The Navy Clothing and Textile Research Facility (NCTRF) previously investigated several methods for producing water turbulence in the hydro-environmental tank (2,3). The methods included metered release of compressed air, pumped flow of water and use of a wave maker (WM). The compressed air method was selected as best suited for the subsequent laboratory tests with human subjects (4.5). Comparisons were made with the results of an ocean field test, conducted at the Coast Guard Station, Cape May, NJ, where the rough seas were generated by the wake of a Coast Guard utility vessel. With a compressed air flow rate of 12 scfm, the decrease in the rectal temperature of the volunteers was less than half the reduction in the ocean field test. Therefore, the additional work reported in this document was undertaken with a wave maker that was installed in the NCTRF hydro-environmental tank. The wave maker is a large piston-driven, anodized aluminum paddle which generates a standing wave with a peak height of up to 0.46 meters at 1.4 second intervals.

A group of eight volunteers was selected with physical characteristics closely matching those of the earlier test group. Rectal temperature, skin temperature and heat flow at twelve sites were recorded by an automated data collection system. The water and air temperatures were 10°C, and the wind speed was 4.5 meters/sec in the NCTRF facility, duplicating the Cape May conditions. The volunteers wore the same Coverall ensemble used in the earlier tests. For safety, personal flotation devices were worn, as well as swimmers' harnesses which were tethered to a cable suspended across the width of the hydro-environmental tank. Although each cold water immersion was scheduled to last 90 minutes, early withdrawal could occur on the decision of the Medical Director or at the option of the volunteer.

The size of the NCTRF hydro-environmental tank accommodated only two volunteers at one time. Three separate wave maker and two calm water trials were conducted with each volunteer. The cumulative results from each trial were analyzed statistically for comparison and also compared with the Cape May results. Each trial was scheduled on separate days in the following sequence: WM1, CW1, WM2, CW2, WM3, followed by any makeup tests. The volunteers were divided into two groups of 4 each; group 1 was tested on day one and group 2 on day 2. This afforded each group a day off between tests.

The results achieved with the wave maker indicate that it represents a significant advance in the simulation of rough sea body cooling rates, compared to the previous Compressed Air Method of water agitation. In the first wave maker trial, it was possible to produce body cooling rates which essentially duplicated the field tests at Cape May. However, the correspondence between laboratory and field only occurred in the first of the three successive wave maker trials. The subsequent two trials yielded much smaller body cooling rates. Since the environmental conditions and the clothing ensemble were identical in the three trials, it is postulated that some type of "learning effect" occurred in the first exposure. As a result, in the subsequent wave maker trials, the volunteers adjusted their posture in the water to diminish their body cooling rate. Most probably, this occurred by reducing the extent of water flushing through the protective garment.

At present, the wave maker appears to be the most promising approach for rough sea simulation in the laboratory. Water agitation in the NCTRF hydro-environmental tank with the wave maker yields body cooling rates 1.6 to 2.7 times faster than calm water exposure and the rate in the first exposure is nearly identical to that in the field test. However, it is necessary to resolve the origin of the "learning effect", which results in smaller cooling rates in the successive wave maker trials. With further study, it should be possible to avoid this effect so that laboratory testing with the wave maker might be used as a reliable substitute for rough sea testing in the field.

I. INTRODUCTION

Accidental water immersion, particularly in rough seas, is a serious problem that threatens the lives of all sailors. In cold water, body heat will be lost despite the use of protective garments. The U.S. Coast Guard (USCG) in 1984 conducted a unique field evaluation on the effect of wave action on human thermal responses to cold water immersion and on the thermal protection afforded by various USCG operational protective garments (1). Two types of protective garments were tested; a wet-suit design that allows water contact with the skin and a dry-suit design that excludes water from contact with the skin. The study demonstrated that, when loosely-fitted, wet-suit garments are worn, body cooling rates were 1.5 to 2.0 times higher in rough seas than in calm seas due to significant flushing of cold water through the garment.

The Coast Guard tests emphasized the importance of conducting water immersion studies in turbulent rather than calm water to accurately assess the thermal performance of protective garments. However, field evaluations are time-consuming, expensive and limited to specific times of the year when acceptable environmental conditions prevail. Therefore, it would be desirable to be able to perform testing in the laboratory where human subjects and thermal manikin studies can be conducted under controlled conditions and with reduced risk. However, for laboratory testing, it is necessary to develop methods of generating turbulent water which reproduce the accelerated body cooling rates of rough sea field testing.

The Navy Clothing and Textile Research Facility (NCTRF) has a hydro-environmental tank in which the water temperature, as well as air temperature, can be tightly controlled. NCTRF previously investigated methods for producing water agitation to simulate rough sea conditions, using a thermal manikin. The methods included the metered release of compressed air, the pumped flow of water and the use of a wave maker (2,3).

In the subsequent testing with human volunteers, the use of diffused compressed air was chosen as the most suitable method to create continuous water turbulence (4,5). Compressed air was released at the bottom of the tank below the volunteer to produce a localized area of turbulent water. Comparisons were made with the results of field testing at the U. S. Coast Guard Station at Cape May. The Cape May tests were conducted with volunteers wearing the Coverall. Turbulent ocean conditions were generated by the wake of a Coast Guard utility vessel which passed the group of volunteers at regular intervals. In the laboratory test of the rough sea simulation, the decrease in rectal temperature achieved with a compressed air flow rate of 12 scfm, was less than half the reduction in the field testing. A decrease in rectal temperature equal to that at Cape May could be obtained by increasing the air flow rate to 13.5 scfm, but this was accompanied by an unacceptable risk of water aspiration with untrained volunteers. It was postulated that the main difficulty with the Compressed Air Method of water agitation was that it failed to reproduce the degree of water flushing through the Coverall that occurred in rough sea conditions.

The present study deals with additional tests of body cooling rates with the water turbulence

generated using a wave maker. The goal of this work was to determine whether cooling rates matching the field tests could be achieved by increasing the extent to which the water flushed through the Coverall. Comparisons were made with the cooling rates determined in the laboratory with calm water as a baseline and with the Cape May results. The group of volunteers was closely matched to the characteristics of the original volunteers and the laboratory conditions; duplicated the water and air temperature, as well as the air velocity of the field tests.

II. APPROACH AND BACKGROUND

A. Physical Characteristics of Volunteers

For the earlier field evaluation conducted at Cape May, NJ, eight volunteer Coast Guard crewmen were selected. For the current laboratory study, eight volunteers were chosen to match as near as possible the physical characteristics of the previous subjects. Each volunteer was interviewed and the nature of the study and the possible risks were explained. The volunteers for the field study were screened by a Coast Guard Medical Officer for any previous cold-related injury and for physical fitness. Because percent body fat and body surface area-to-mass ratio largely determine the response to cold water immersion, a homogenous group of volunteers was selected with the required characteristics. Body fat, calculated for the field test volunteers from the sum of four skinfolds (6), average 13.2 ± 1.5%, agreed very well with body fat determined from hydrostatic weighing (7), average 13.5 ± 2.0 %. A comparison between the characteristics of the two groups of test subjects in Table 1, indicates that there were no significant differences in height and percent body fat. However, there were significant differences in age, weight and body surface area between the two groups.

B. Field Evaluation

1. Test Site Conditions

The rough sea field testing and evaluation were conducted at the U.S. Coast Guard Station, Cape May, NJ with an unused boat house provided by the U.S. Coast Guard Training Center. The environmental conditions measured during the tests were: ambient temperature, 9.2±2.6°C; water temperature, 9.4±1.0°C and wind speed, 4.5 m/s (10 mph). The April time frame for the field evaluation was planned because of the expected milder ocean temperatures.

2. Method of Rough Sea Generation

In the field tests, water agitation to create rough sea conditions was generated by the wake of a Coast Guard 41-foot utility vessel which traveled past the line of tethered volunteers at 45 to 60 second intervals. Wave height averaged between 1.2-1.8 m (4-6 feet) and wave frequency averaged 1-1.2 waves per minute. This corresponds to a Beaufort Sea State Scale of 4-5. The sea state created in this manner had been used previously and shown to realistically simulate a rough sea environment (1).

3. Body Temperature Measurements

Skin temperatures were measured with surface temperature thermistors at five sites: chest, back, forearm, medial thigh, and calf. Rectal temperature was measured with a thermistor inserted approximately 10 cm beyond the anal sphincter. The skin and rectal temperature thermistors were hardwired into a waterproof harness, approximately 1.8 m in length. The harness terminated at a waterproof, multi-pin connector. Each volunteer was assigned his own harness, which coupled with waterproof connectors to a 30-m length of waterproof cable. In turn, the 30-m cable was connected to a computerized data acquisition system, which was located in the boat house.

4. Safety Procedures

The following safety procedures were used during all of the field tests: each volunteer wore a swimmer's harness tethered to a cable suspended between the boat house and a pylon located approximately 6 m away; a rescue boat, operated by an experienced coxswain and at least one crew member was stationed in close proximity at all times; a Medical Officer was on the utility boat or in the water at all times; medical life support personnel and equipment were available in the boat house and within 0.8 km of the field test site and a hot water (38°C) shower was available at the rewarming site. In addition, all test volunteers were experienced swimmers. A volunteer's exposure was terminated for any of the following reasons: completion of the 90-min exposure; rectal temperature reached 35°C; skin temperature at any site reached 4.4°C; the volunteer showed signs or symptoms of impending cold injury, or unusual distress; the Medical Officer requested termination, or the volunteer requested voluntary termination.

5. Testing Procedure

The volunteers were split into two groups; the morning group reported at 0700 hours and the afternoon group reported at 1300 hours. Each volunteer was instrumented with his temperature harness, which was checked for proper operation prior to donning the protective clothing. Once dressed, the volunteers entered a 12-foot Rigid Hull Inflatable (RHI) utility boat that transported them to the test site. At the test site, each volunteer's swimming harness was attached to the safety tether. When all volunteers had been connected to the data acquisition system, data collection began. After the data for time zero had been collected, the volunteers entered the water and assumed a cold water survival position (arms crossed, knees drawn up). As soon as the RHI utility boat was clear, the Coast Guard's 41-foot boat began generating waves. Data were collected every 20 seconds. At the end of two minutes the data were averaged, printed and plotted. Data were also saved on a disk every ten minutes, which prevented excessive loss of data in case of power failure.

6. Clothing System

Three protective clothing systems were evaluated in the field tests: a) Anti-Exposure Coverall; b) Coverall plus Shorty Wet Suit and c) Float Coat. Only the Coverall was used in the present

laboratory evaluation, since the Coverall was the clothing tested in the previous laboratory study and the earlier thermal manikin evaluation of laboratory rough sea simulation. The Coverall ensemble (Figure 1) consists of the following items: one-piece coverall (used by U.S. military aircrew personnel) consisting of an aramid fire-retardant outer and inner shell with foam insulation (3 mm PVC), worn over gym shorts and cotton long underwear (shirt and drawers); wool/cotton socks; leather work boots; diver's, three-fingered mittens (3 mm Neoprene); surf cap (3 mm Neoprene); life preserver unit (LPU-26/P) and swimmer's harness.

C. Laboratory Evaluation

1. Rough Sea Simulation Methods

The laboratory evaluation was conducted in the NCTRF hydro-environmental tank in Natick, MA. The hydro-environmental tank measures 6.7 meters long, 4.3 meters wide, 2.6 meters high (22x14x8.5 feet) and was described in detail in an earlier report (3). The wave maker used in the current study consisted of a paddle that was fabricated from anodized aluminum and mounted on roller bearings attached to the deck of the tank. The 84-inch wide paddle was immersed 13 inches into the water and was driven by a 2-inch diameter piston, that was suspended from an I-beam that runs down the length of the ceiling. The piston was operated by a digitally-timed solenoid valve which was programmed to switch the solenoid every 0.7 seconds, based on the natural frequency of the pool. The in and out movement of the piston pushed the water back and forth, generating a standing wave at intervals of 1.4 seconds, with peak heights of 0.30 to 0.46 meters and a peak width of 1.8 meters. Figure 2 provides a diagram of the wave maker setup and also indicates the relative position of the test subject in the hydro-environmental tank.

Preparatory thermal manikin testing and a pilot study with a human subject demonstrated that the wave maker was capable of producing larger body cooling rates than the Compressed Air Method. The wave maker causes water to wash over the head and or neck regions, duplicating the effect produced by the wake of the Coast Guard vessel at a frequency of 1 to 1.2 times a minute in the field tests. The much higher frequency of the laboratory wave action substantially increased the risk of aspiration. To minimize this risk, an operating pressure of 50 psi was chosen for the solenoid which limited the maximum wave height to 1.5 meters.

2. Testing Routine

The volunteers were divided into two groups of 4 each. Group 1 was tested on day one; group 2 was tested on day 2. As a result, each group had a day off between tests. The schedule for the tests, each performed on a separate day was WM1, CW1, WM2, CW2, WM3, followed by any makeup tests. The volunteers were asked to report two at a time at different times during the day, between 0700 and 1430 hours, since testing was limited by the dimensions of the hydro-environmental tank to two volunteers at the same time. Each volunteer was fitted with his instrumentation harness, which was checked for proper operation prior to dressing in the Coverall described earlier. Goggles were worn to protect the eyes from the water. During cold water

immersion, the volunteer's rectal temperature was measured with a thermistor as described for the field tests. Skin temperature and heat flow were measured at twelve sites with thermistors and heat flow sensors.

Once dressed, the two volunteers walked upstairs to the test chamber where the tank is located. They were then connected to the waterproof data acquisition cable. When both volunteers were connected, the data collection began. Following acquisition of the zero time data, the volunteers entered the tank, the swimmer's harness was connected to a safety tether, and the volunteers assumed the survival position. The tether kept the volunteer centered rather than drifting to the sides of the pool due to the wave action, but otherwise did not restrict movement. Water temperature was maintained at 10°C and air temperature was 10°C with a wind speed of 4.5 meters per second, duplicating the conditions at Cape May. Data were collected every 20 seconds and at 2 minutes the data were averaged, printed and plotted. Data were also saved on a disk every ten minutes to prevent excessive loss of data in case of a power failure.

3. Safety Procedures

Each cold water immersion was scheduled to last 90 minutes. However, the same termination criteria used for the field testing were used in the laboratory. The early termination criteria included: reaching a rectal temperature of 35°C, skin temperature 4.4°C, voluntary withdrawal, or withdrawal at the discretion of the Medical Director. Each volunteer wore a personal flotation device and his swimmer's harness was tethered to a cable suspended across the width of the hydro-environmental tank. Two technicians were in the test chamber and a Medical Officer was present at all times. Medical life support personnel and equipment were available nearby. A hot water shower was available in the laboratory.

III. RESULTS AND DISCUSSION

The mean exposure time for volunteers in the two calm water immersion trials and the three successive wave maker tests is illustrated by the bar chart in Figure 3. During the wave maker trials, 30% of the terminations occurred because the volunteer's core temperature reached the safety temperature limit of 35°C. The remaining volunteers withdrew voluntarily, due to various symptoms, which included muscle cramps and extreme discomfort. The increasing tolerance times of 51, 61 and 66 minutes noted in Figure 3 for wave maker trials 1, 2, and 3 respectively, were not judged to be statistically significant because of the variability of human responses. There were also no significant differences in the tolerance times between the two calm water trials, but it should be noted that these times were significantly longer than the immersion times tolerated by the volunteers in the wave maker trials.

The population mean change in rectal temperature with time during the calm water (open points) and wave maker trials (filled points) is represented in Figure 4. Due to the early terminations in the wave maker trials, the statistical analysis was limited to the data obtained for periods of 50 minutes or less. The accuracy of the thermistor core/skin temperature sensors is ± 0.1°C and

differences in rectal temperature of 0.1°C are considered to be statistically significant. The first wave maker trial produced a decrease in core temperature at 50 minutes which was significantly larger, almost 0.5°C, than the average decrease in trials 2 and 3 at 50 minutes. There were no significant differences between wave maker trials 2 and 3 and there were no significant differences between the two calm water trials.

The change in the population average of the mean weighted skin temperature (MWST) with time is shown in Figure 5. At 50 minutes the MWST in wave maker trial 1 had dropped by 10.2°C compared to the zero time value. The temperature at 50 minutes was significantly lower (18.2 °C) than the average of wave maker trials 2 and 3 (19.5°C). There were no significant differences between the MWST in wave maker trials 2 and 3 or between the values in the two calm water trials. However, it should be noted that the average MWST in the first trial at 50 minutes was 6°C lower than the average of the two calm water trials (24.7°C).

The average heat flow, which represents a measure of the rate of energy loss by the body, is depicted in Figure 6 as a function of immersion time. As a basis of comparison, the heat flow for the resting human in air at thermal equilibrium, wearing the average business suit, would be approximately 54 Watts/m^2. The thermal conductivity of water is approximately twenty times that of air. The heat loss sustained by the volunteers wearing the protective garment in calm water at 10°C averaged 285 Watts/m^2. In the wave maker trials the highest heat loss was 714 Watts/m^2 after 10 minutes, decreasing gradually to values of 430 to 500 Watts/m^2 at 50 minutes. The differences in heat flow at 50 minutes for the wave maker trials were not significant and averaged 466 Watts/m^2. This compares to an average heat flow of 285 Watts/m^2 for the calm water trials. Thus, use of the wave maker increased the heat loss by a factor of 1.6 compared to the calm water conditions.

In addition to the foregoing laboratory comparisons which indicate the advantage of the wave maker in increasing the body cooling rate, it is important to make a comparison with the results of the ocean testing conducted at Cape May. Figure 7 offers a comparison of the change in rectal temperature in the three wave maker trials (filled points compared with the Cape May results (open points). The body cooling rate in the first wave maker trial parallels the field results as a function of time. The total change at 50 minutes, 1.17°C is 82% of the field result, 1.42°C. The body cooling rate of the second and third wave maker trials are much smaller, as indicated earlier, and similar to each other. It is significant to observe that it took 15 minutes before the rectal temperature began to drop in the second and third wave maker trials and the rate of change was never as large as the first wave maker trial and the field trial.

IV. Conclusions

The wave maker represents a significant advance in the ability to simulate rough sea body cooling rates in the laboratory compared to the previous Compressed Air Method of water agitation Using the wave maker in the NCTRF hydro-environmental tank under the conditions described, it was possible to produce body cooling rates which essentially duplicated the field results in the ocean tests at Cape May with the same Coverall protective clothing system. The increase of the body cooling rate with time was parallel to the measurements at Cape May, although the rectal temperature measured in the field tests at 50 minutes was slightly lower. However, the correspondence between the laboratory and field only occurred in the first of the three successive wave maker tests. The subsequent two trials yielded much lower body cooling rates. The environmental conditions, air and water temperature, wind speed and water agitation, were identical in the three trials, as was the clothing ensemble. The Coverall worn during these trials is a protective garment of the wet-suit design, which allows water to flush through the garment under the wave action. Therefore, it is postulated that some type of test subject "learning effect" occurs in the first exposure. As a result, the volunteers adjusted their posture in the water so as to diminish the body cooling rate, most probably by reducing water flushing through the protective garment.

It is possible that, if the volunteers wore a protective dry suit, the body cooling rates would be more reproducible in successive exposures. In any case, the pattern in body cooling rates in the successive wave maker tests should alert researchers to the possibility that similar problems could arise in simulated rough sea testing. The most important observation in this study is that water agitation in the NCTRF hydro-environmental tank with the wave maker yields body cooling rates 1.6 to 2.7 times faster than calm water exposure. Also, in the first wave maker exposure the body cooling rate is nearly identical to the field test. Accordingly, at present, the wave maker appears to be the most promising rough sea simulation method in the laboratory. However, it is necessary to resolve the origin of the "learning effect", which results in the lower cooling rates of the successive wave maker trials. If it is possible to devise a method of avoiding this effect, the wave maker could be relied on as a laboratory method of rough sea simulation to reduce or replace the need for field testing.

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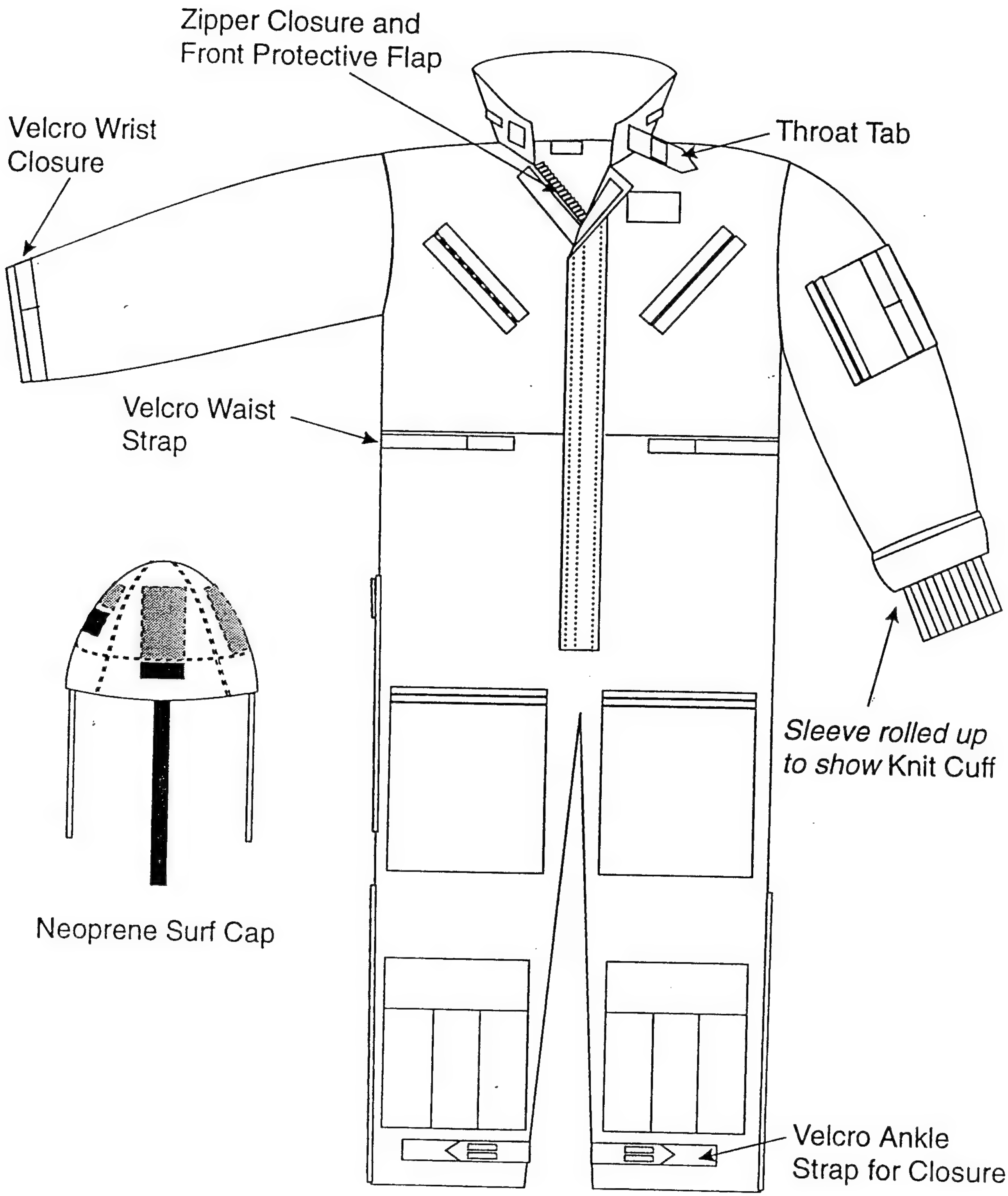

Figure 1. Anti-Exposure Coverall

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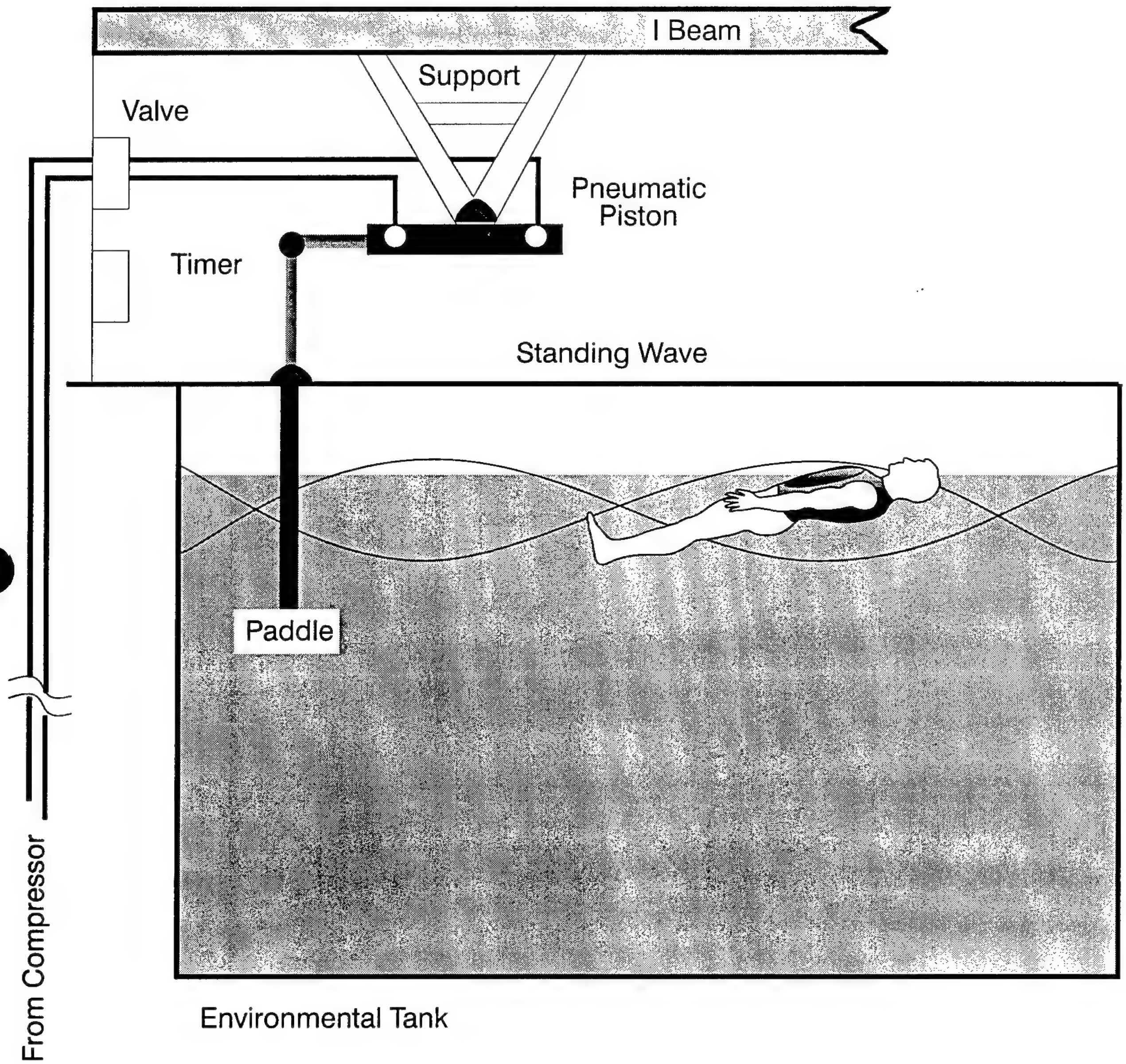


Figure 2. Wave Maker

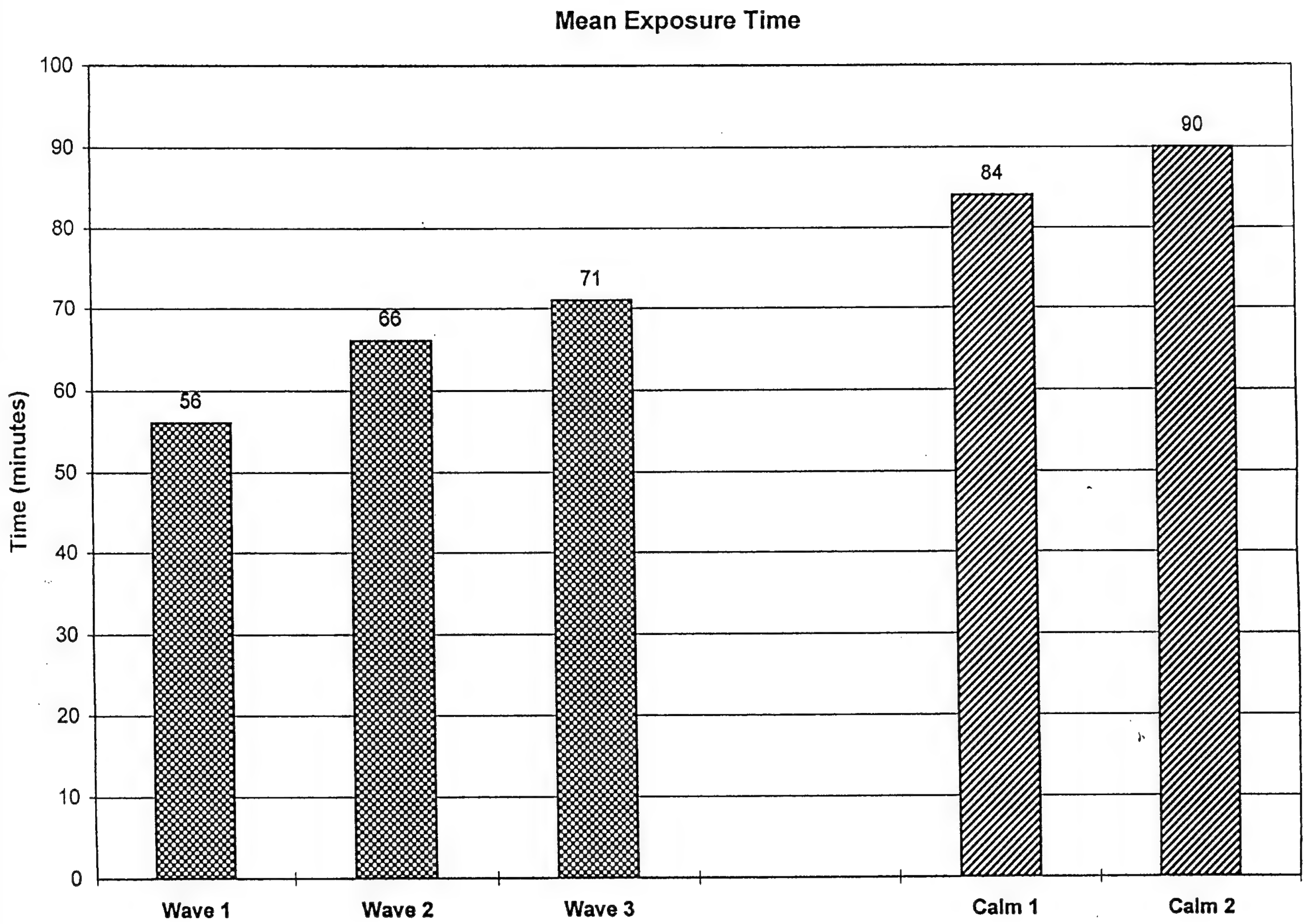
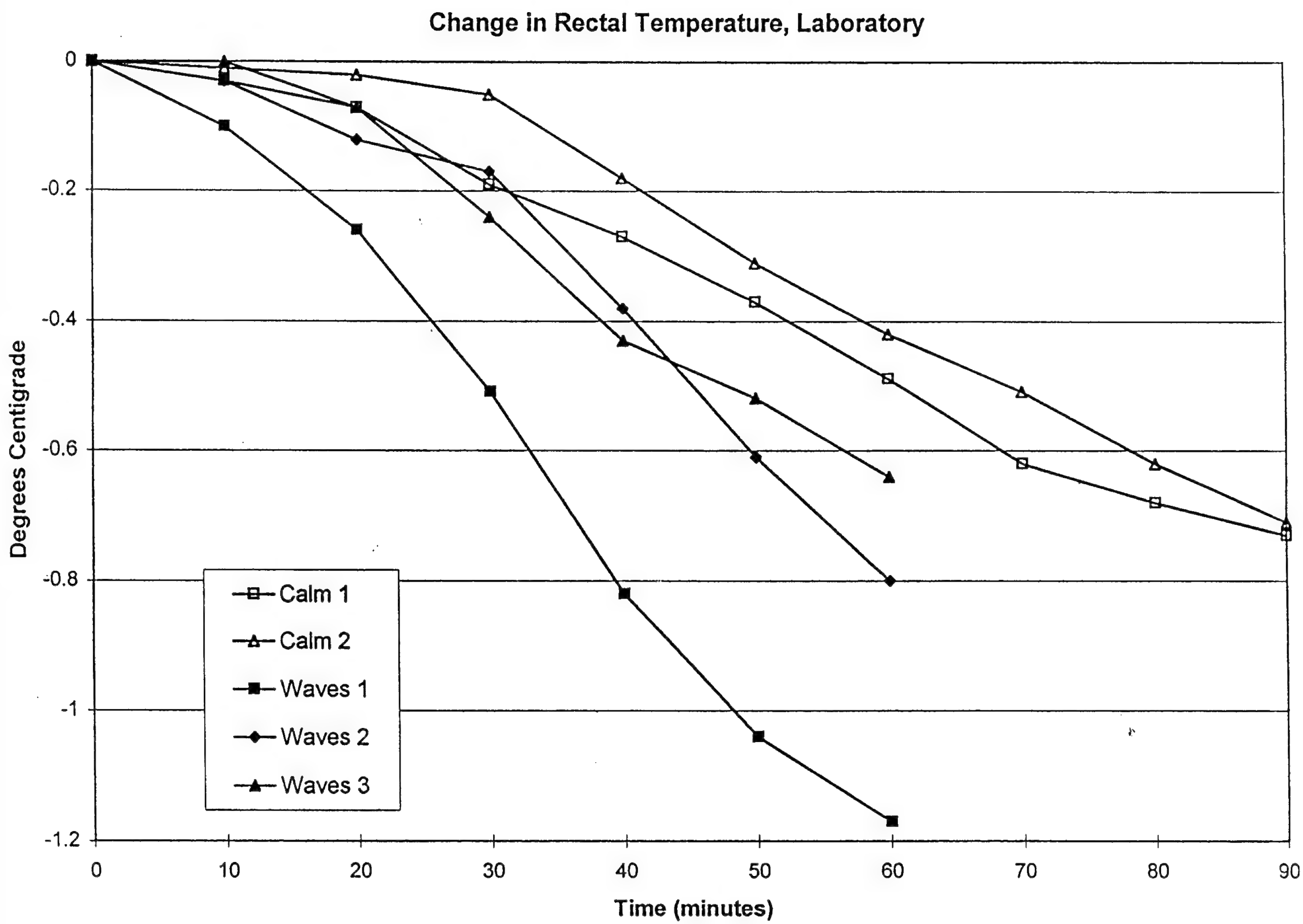

Mean Exposure Time
Time (minutes)
100
90
80
70
60
50
40
30
20
10
0
56
66
71
84
90
Wave 1
Wave 2
Wave 3
Calm 1
Calm 2

Figure 3.


Change in Rectal Temperature, Laboratory
Degrees Centigrade
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-0.4
-0.6
-0.8
-1
-1.2
0
10
20
30
40
50
60
70
80
90
Time (minutes)
Calm 1
Calm 2
Waves 1
Waves 2
Waves 3

Figure 4.

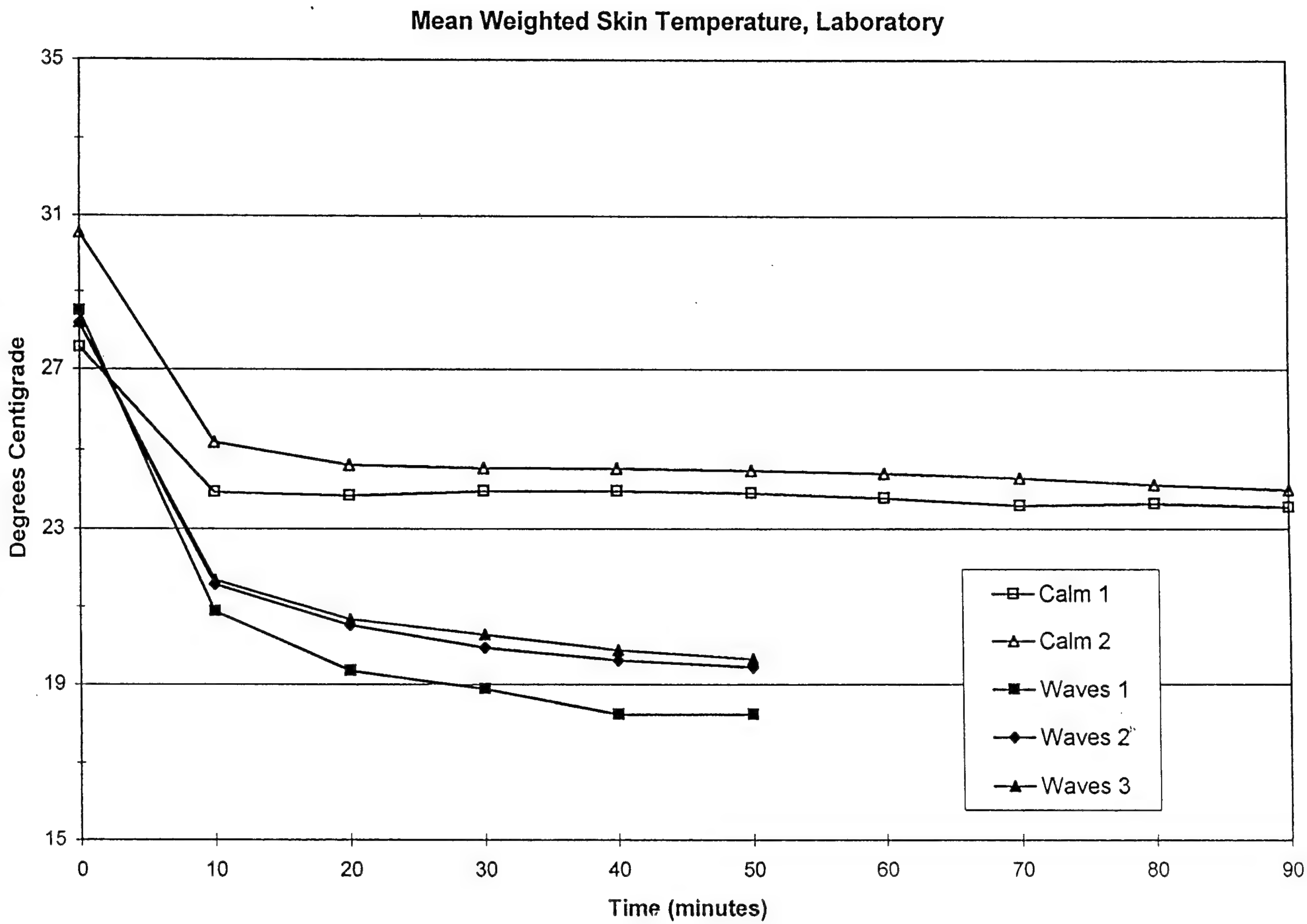

Mean Weighted Skin Temperature, Laboratory
Degrees Centigrade
35
31
27
23
19
15
0
10
20
30
40
50
60
70
80
90
Time (minutes)
Calm 1
Calm 2
Waves 1
Waves 2
Waves 3

Figure 5.

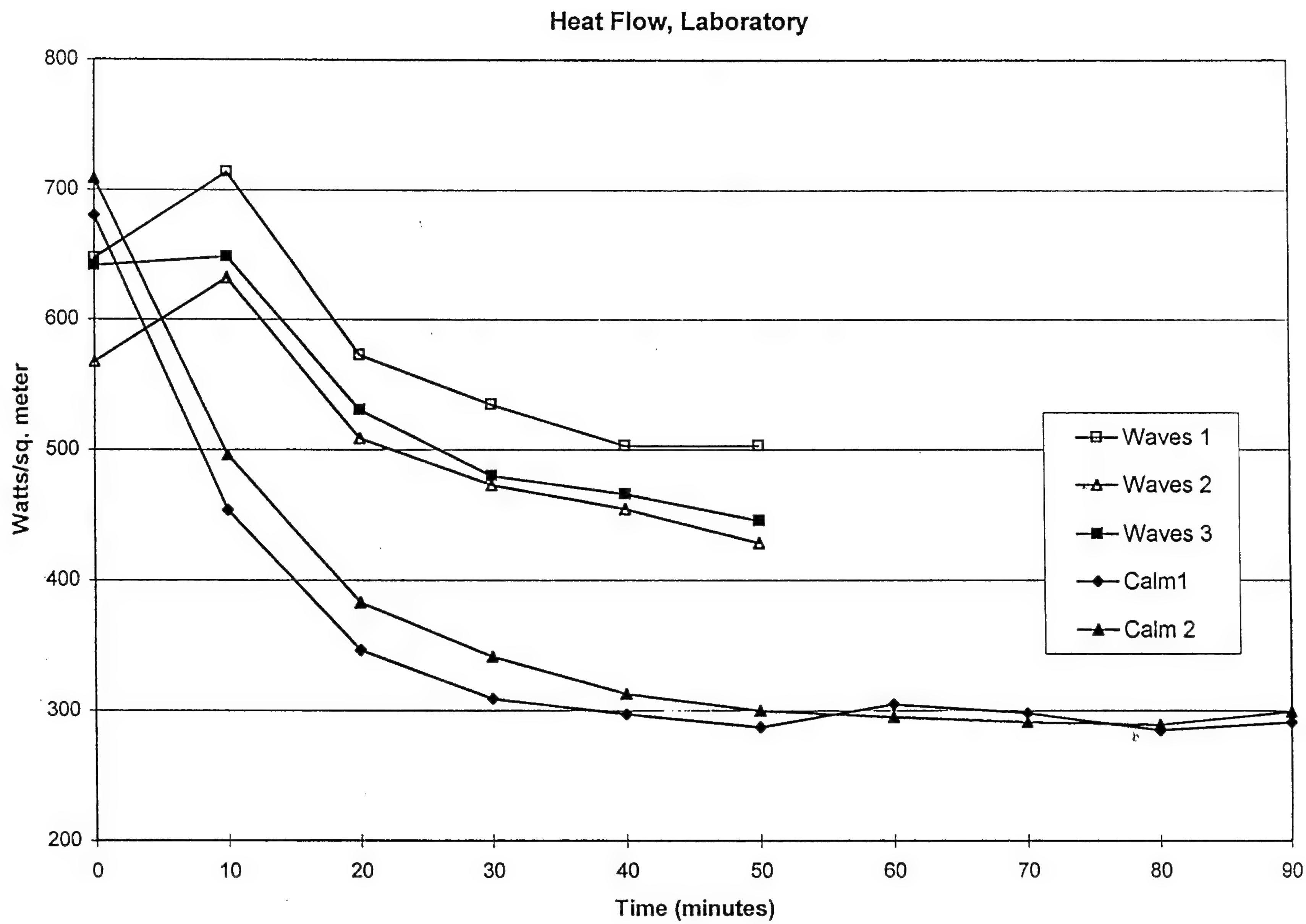
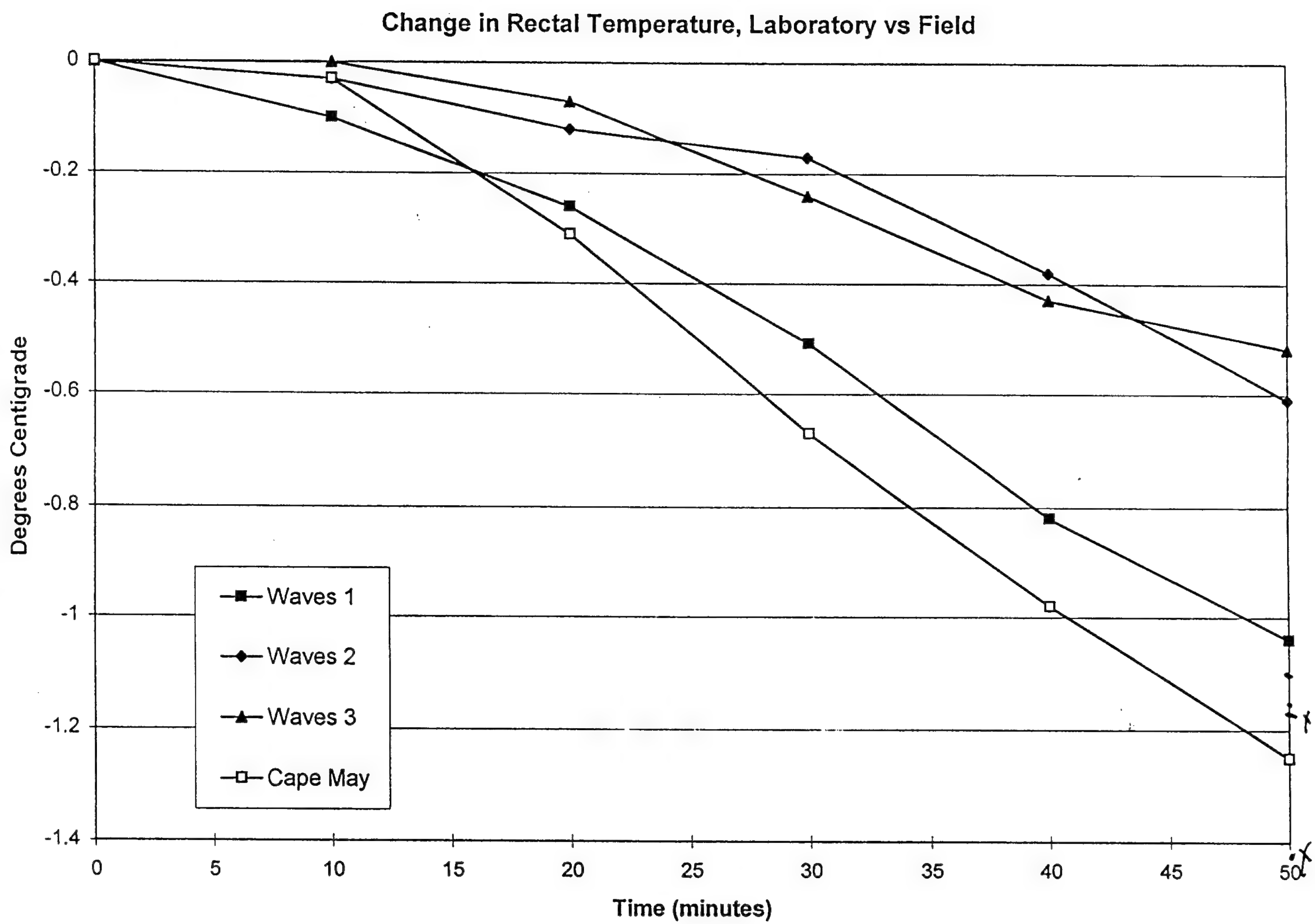

Heat Flow, Laboratory
Watts/sq. meter
800
700
600
500
400
300
200
0
10
20
30
40
50
60
70
80
90
Time (minutes)
Waves 1
Waves 2
Waves 3
Calm1
Calm 2

Figure 6.


Change in Rectal Temperature, Laboratory vs Field
Degrees Centigrade
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-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
0
5
10
15
20
25
30
35
40
45
50
Time (minutes)
Waves 1
Waves 2
Waves 3
Cape May

Figure 7.

Table 1: Physical Characteristics of Volunteers

	Age (year)	Height (cm)	Weight (kg)	Body Surface Area (m^2)	Body Fat (%)
Laboratory					
Mean	18.5	179	79	1.98	15.2
Standard Deviation	0.5	7	9.6	0.15	3.2
Previous Field Study					
Mean	25	175	68.4	1.83	13.5
Standard Deviation	5	3	5.4	0.07	2

REPORT DOCUMENTATION PAGE

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13. ABSTRACT *(Maximum 200 words)*

The study was undertaken to determine whether the measurements of fabric resistances on the Guarded Hot Plate (GHP) could be used to predict the insulation performance of typical military garments as an alternative to full thermal manikin (TM) testing. Six items of military issue were selected, varying from lightweight permeable to heavy weight impermeable clothing. Clothing resistances were calculated as the sum of fabric, interlayer and boundary layer resistances for comparison with thermal and evaporative resistances measured on the clothed thermal manikin. There was good agreement between the measured and calculated values of the thermal resistances for the two heavy, impermeable garments, but large differences for the four clothing items with air permeable fabrics or impermeable but relatively thin material. There was reasonable agreement between the calculated and measured values of the evaporative resistances for the torso but large differences for the arms and legs. The first problem is due to convection in the air layer between the TM skin and the clothing. The second problem is due to the obstruction of air flow by the clothing, e.g., in the area between the legs. Improvements in the prediction of clothing insulation performance will require an evaluation of the role of clothing materials on convection in the interlayer air and of the and bulkiness of the clothing on the airflow.

14. SUBJECT TERMS

Clothing insulation performance, clothing thermal resistance, clothing evaporative resistance guarded hot plate testing, thermal manikin testing,

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CORRELATION OF THERMAL AND EVAPORATIVE RESISTANCES FOR MILITARY CLOTHING ITEMS, MEASURED ON A GUARDED HOT PLATE AND A THERMAL MANIKIN

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SUMMARY

The thermal resistance of garments is an essential factor in protecting military personnel from the rigors of cold weather operations. However, when operating in hot, humid conditions, the evaporative resistance of the garment can contribute to heat stress. The present study was undertaken to determine whether the measurements of fabric resistances conducted on the Guarded Hot Plate (GHP) can be used to predict the insulation performance of typical military garments as determined on the clothed Thermal Manikin (TM). If this goal could be realized, it would provide a rapid method of screening the fabric constructions for improvements in military clothing performance, and would also provide an alternative to the costly and time consuming full thermal manikin testing for clothing acceptance. The approach involved the evaluation of the thermal and evaporative insulation performance of a selection of military essential garments, including items designed for hazardous duty, such as fire fighting and hazardous chemical cleanup.

The utility of simple, series models of the contributing thermal and evaporative resistances for estimating the insulation performance of civilian clothing has been demonstrated in the work at a number of agencies. The body and clothing are treated as a set of cylindrical segments consisting, e.g., of the torso, two arms and two legs. The contributing resistances, consisting of the fabric layers, the intervening air spaces and the external boundary layer resistance, are summed for each of the individual clothing segments. These segment resistances, properly weighted by the clothing segment area, are then added as a set of resistances in parallel to obtain the average resistance of the clothing ensemble. In the present work, the terminology and modeling developed by McCullough at the Institute for Environmental Research, Kansas State University, has been followed (2-4).

In the work reported herein, measurements of the fabric thermal and evaporative resistance were made on an instrumented Sweating Guarded Hot Plate, which was subjected to an air flow parallel to the surface. The clothing thermal and evaporative resistances were determined on a fully instrumented thermal manikin, equipped with an automated data acquisition system. The thermal manikin is located in a temperature and humidity controlled environmental chamber and is subjected to a frontally directed air stream. A tight-fitting knit fabric, wetted by water pumped through perforated Tygon® tubing, serves as a sweating skin for the measurement of clothing evaporative resistance.

Heat loss measurements are obtained for each of the individual body segments. Thermal resistances are automatically calculated from the power required to maintain the temperature gradient between the thermal manikin skin and the ambient air. Evaporative resistances are calculated from the power required to maintain the combined water vapor pressure and thermal gradients between the thermal manikin skin and the ambient air. Three separate sets of measurements were taken for each clothing ensemble for both the thermal and evaporative resistances.

The following six clothing items were selected as representative items of military issue; 1) Disposable Coverall; 2) Men's Coverall; 3) Aramid Coverall; 4) TAP Suit; 5) Anti-exposure Coverall; and 6) Firefighter's Coverall. It was expected that this selection would provide a wide range of thermal and evaporative resistances to support an evaluation of the approaches for predictive modeling. The

parameters characterizing the garments were the clothing radius, determined from measurements on the clothed manikin, and the fabric thickness.

An initial attempt was made to correlate the thermal resistance of fabric samples measured on the Guarded Hot Plate directly with the average clothing thermal resistance measured on the thermal manikin. The measured values were first corrected for the boundary layer resistance to obtain the intrinsic values of the clothing and fabric resistance. A least squares plot indicated that there was poor correlation between the intrinsic clothing and intrinsic fabric resistances. The difficulty was attributed to neglect of the interlayer air resistance, the air layer between the clothing and thermal manikin, which was not included in the correlation. The interlayer air resistance, as calculated from an analytical formula for the sum of the radiative heat transfer coefficient and air thermal conductivity, proved to be a significant fraction of the total measured clothing resistance. However, inclusion of the interlayer air resistance in the calculation of the clothing resistance from the fabric resistance failed to improve the correlation with the measured clothing resistances.

Unless the fabric is very thick, as is the case with the Anti-exposure Coverall and the Firefighter's Coverall (Figures 7&8), the clothing resistance will be dominated by the boundary layer and interlayer air resistances. Therefore, for a useful prediction, it is important that these two air resistances be accurately measured and properly represented in any modeling. However, neither one of these resistances can be measured directly with the clothing in place on the thermal manikin. An examination of the several contributions to the calculated clothing segment resistances suggested that the magnitude of the interlayer air resistance was overestimated by the analytical formula. Three of the six clothing items, the Disposable Coverall, Men's Coverall and Aramid Fire Resistant Coverall, are constructed with thin, air permeable fabrics and the TAP suit, although not air permeable, is also relatively thin. For these clothing items it is necessary to take account of convection in the interlayer air. The factor required to reduce the interlayer air resistance to obtain agreement between the calculated and measured clothing resistances proved to be nearly identical for the three air permeable clothing systems. This suggests that the modification to include convection is physically realistic.

Measurements of the evaporative resistances of the clothing segments were conducted on the four air permeable clothing items, which included the Firefighter's coverall. There was reasonable agreement between the calculated and measured values for the torso but, in most cases, large differences for the arms and legs. Both the boundary layer thermal and evaporative air resistances, which are required in the calculation of the evaporative resistance from the fabric values, are estimated from measurements on the bare thermal manikin. However, the profile presented by the clothed thermal manikin can be very different from that of the bare thermal manikin. If the flow of air is obstructed by the clothing, as occurs in the area between the legs, it can lead to a large increase in the measured resistance. This would account for the differences between the calculated and measured values for the affected clothing segments.

In summary, this study has shown that it is not possible to make a successful correlation directly between the fabric thermal and evaporative resistances measured on the Sweating Guarded Hot Plate and the clothing resistances measured on the thermal manikin. The correlations require the use of

models which include proper estimates of the boundary layer and interlayer air resistances. The standard model for the thermal resistance, developed by McCullough, works well when the fabric resistance is large, as with the Anti-exposure Coverall and the Firefighter's Coverall. But with air permeable and thinner clothing, it is necessary to modify the estimate of the interlayer air resistance to take account of convection. The differences between calculated and measured values of the evaporative resistance can be traced to the change in air flow around the body segments of the clothed manikin, compared to the bare manikin, which affect the measured resistances. The improved understanding of these factors, which is provided by this study, should lead to improvements in the test methodology and to improvements in the prediction of clothing performance from fabric measurements.

I. INTRODUCTION

The thermal resistance of garments is an essential factor in protecting military personnel from the rigors of cold weather operations, allowing them to carry out designated assignments with greater safety and efficiency. However, when operating under hot, humid conditions, the evaporative resistance of the garment can contribute to heat stress. This can limit the level and duration of strenuous activity which military personnel can perform.

The Navy Clothing and Textile Research Facility (NCTRF) has conducted studies of fabric and clothing insulation performance using a Guarded Hot Plate and an instrumented thermal manikin. Both dry thermal resistance and evaporative resistance measurements can be made with these systems. The goal of the present study is to determine whether results obtained on the Guarded Hot Plate can be used in empirical correlations, or by model calculation of the component resistances, to predict the insulation performance of the typical military garments as determined on the clothed thermal manikin. The approach involved an examination of the thermal and evaporative insulation performance of a selection of military essential garments, including items designed for hazardous duty such as fire fighting and hazardous chemical cleanup.

Pioneering work on heat stress and the insulation performance of military clothing had been conducted at the US Army Research Institute of Environmental Medicine (USARIEM) and is summarized in a report (1). In addition, the work by groups at the Institute for Environmental Research, Kansas State University (2-4); the Laboratory of Heating and Air-Conditioning, Technical University of Denmark (5,6); and the Technical University of Delft (7-10), have demonstrated the utility of simple series models of the component clothing resistances in estimating the thermal and evaporative insulation performance of civilian clothing. The models commonly treat the body and the clothing as a set of cylindrical segments. The system thermal resistances, consisting of the fabric layers, the intervening air spaces and the external boundary layer resistance are summed for each segment to obtain the thermal resistance of the individual clothing segments. The clothing segment resistances, properly weighted by the segment area, are then added as a set of resistances in parallel to obtain the average clothing resistance. The published literature has also provided important details on the procedures for determining the geometrical clothing factors and component thermal or evaporative resistances which cannot be measured directly.

The present study is somewhat limited by the small size of the sample selection of military issue garments and, to an extent, by the unexpected similarity in insulation characteristics for a number of garments. However, these limitations were offset by examining correlations between measured and calculated resistances for the individual clothing segments, in effect increasing the size and diversity of the sample population. In addition, correlations were made using the average clothing resistances, obtained by appropriate summation over the clothing segment values. Thus, it has been possible to draw conclusions about some important factors which affect clothing performance and which must be considered in pursuing correlative or predictive relations. The methods should have utility in screening fabric constructions for insulative clothing applications and in designing improvements in the test methodology and analysis.

II. EXPERIMENTAL

1. The Sweating Guarded Hot Plate

The Sweating Guarded Hot Plate (Figure 1) consists of a temperature controlled heated area, 10 by 10 inches, and a surrounding guarded area with external dimensions of 20 by 20 inches. The instrument is located in a temperature and humidity controlled chamber and subjected to an air flow parallel to the surface with an average velocity of 1 m/sec. When used for measuring the evaporative resistance of textile materials, water is maintained in the cavity below the sintered plate by gravity flow through a heat exchanger from a reservoir outside the test chamber. The sintered plate is covered by a sheet of cellophane which allows water vapor to diffuse through but protects the fabric sample from wetting by liquid. The system is monitored by thermistor temperature sensors connected to a computer controlled data acquisition system which records the surface temperature, air temperature, and power as a function of time and provides a computation of the resistance in terms of clo units. In the procedure followed in this and other such studies, measurements were made on swatches of material cut from the clothing systems that were used in a series of thermal manikin tests. Three repeat measurements were made on the clothing samples and the mean and standard deviations were calculated.

2. The Thermal Manikin

The thermal manikin (TM) is used to measure dry thermal insulation and water vapor permeability of clothing ensembles.. The manikin was designed to correspond to a 50th percentile adult male; height, 70 in. and weight, 155 lbs. It is constructed from aluminum castings for high thermal conductivity so that a uniform surface temperature can be maintained by a small number of strip heaters cemented to the inner surface of the manikin. The maximum power input is 1200 watts and the temperature is sensed at a large number of locations using individually tested and qualified thermistors which can be interchanged with a reproducibility of ±0.1°C. Low thermal conductivity spacers between adjacent sections, e.g., arm and hand, limit the heat transfer between sections. A tight-fitting knit fabric, wetted by water pumped through perforated Tygon® tubing, serves as a sweating skin for the measurement of clothing evaporative resistance (Figure 2). The thermal manikin is located in a large environmental chamber which is temperature and humidity controlled. Blowers produce an air stream, with an average velocity of 1m/sec which is directed frontally, i.e., normal, to the manikin.

Power input to the heaters is computer controlled and the data acquisition system stores air temperature, dew point, the surface temperature and power data for the various sites on the thermal manikin. A trace of the time history allows the determination of steady state operating conditions for the automatic calculation of thermal resistance in resistance units and evaporative resistance in terms of the dimensionless ratio, i_m (a measure of the water vapor permeability).

A summary of the geometrical characteristics and the boundary layer air resistances determined on

the bare thermal manikin is presented in Table 1. Due to the variation in the contour of the body segments, the surface area was determined directly by measuring the area of adhesive tape applied to cover the individual body segment. Corresponding radius values, r_1, were calculated using the segment length. These results are recorded in the upper section of Table 1. In addition, measurements were made of the circumference of the individual body segments at three locations, designated a, b and c, and the results were averaged to determine a radius, r_2. The ratio r_1/r_2 was used as a correction factor for the clothing radius, as described below.

3. The Collection of Test Garments

The following six clothing items were selected as representative items of military issue:
1) Disposable Coverall (MIL-C-29133) lightweight, permeable, consisting of a nonwoven cloth composed mainly of polypropylene (Figure 3);
2) Men's Coverall (MIL-C-8700) lightweight, permeable, comprised of a polyester and cotton blend (Figure 4);
3) Aramid Coverall (MIL-C-87093) medium weight, permeable, comprised of a plain weave aramid cloth (Figure 5);
4) TAP Suit (MIL-C2181) medium weight, impermeable, comprised of a butyl-coated nylon cloth (Figure 6);
5) Anti-exposure Coverall (MIL-S-29109) heavy weight, impermeable, comprised of a chloroprene-coated nylon with an elastomeric foam interlayer and nylon taffeta lining (Figure 7);
6) Firefighter's Coverall (MIL-C-24935) heavy weight, permeable, comprised of an outer aramid and polybenzimidazole blend fabric, an interlining of a microporous film laminated to an aramid fabric and lined with an aramid quilted batting (Figure 8).

It was hoped that this selection would provide a wide range of thermal and evaporative resistances to support an evaluation of the approaches for predictive modeling. Parameters characterizing the various garments are cited in Table 2. The clothing segment radius was determined from measurements of the circumference of the segment on the clothed manikin at the same three locations used in measurements on the bare thermal manikin, described above. The radius obtained as the average value, which is listed in Table 2, was multiplied by the thermal manikin radius ratio, to obtain the corrected radius used in the computation of the air layer thickness and the clothing area factor.

The arms of the thermal manikin are articulated at the shoulder joint to facilitate dressing the manikin. In the present study, the thermal manikin was dressed with a particular clothing ensemble. For thermal resistance measurements, this included footwear, gloves and head covering. Three individual measurements of the clothing thermal resistance were made for each clothing ensemble. The tests were conducted without completely removing the clothing to avoid having to move the manikin but the clothing was stripped to the ankles between repeat measurements in order to include the variability of dressing the manikin. This schedule of thermal resistance measurements was completed for the entire set of six clothing items. The thermal manikin was then dressed for the series of evaporative resistance measurements. The clothing did not include gloves or head protection, but otherwise was the same as that used for the thermal resistance measurements. Mean values and

standard deviations were calculated from the three experimental measurements.

III. RESULTS AND DISCUSSION

1. Determination of the Thermal Resistance

a. Guarded Hot Plate Measurements

The resistance to dry heat transfer, R_t, for a fabric, including the boundary layer air resistance, measured on the guarded hot plate (GHP) is determined by the power, Q_t, required to maintain a defined temperature gradient:

$$R_t = \frac{(T_s - T_a)A}{Q_t} \quad \textbf{(1)}$$

where:

R_t = resistance to heat transfer, °C m²/W
A = hot plate surface area, m²
T_s = hot plate surface temperature,°C
T_a = air temperature,°C
Q_t = power or heat flow, W

The resistance to heat transfer is also frequently represented as a clothing insulation value, clo, the amount of insulation necessary to maintain a temperature gradient of 0.18°C with heat flow of 1 kcal/m² hr, i.e., 1 clo = 0.18°C-m² /kcal. Since 1 W = 0.86 kcal, the relationship between clo and thermal resistance is:

$$clo = 6.45 R_t \quad \textbf{(2)}$$

Measurements were made on the GHP with a typical surface temperature of 34.6°C, air temperature

$$R_f = R_t - R_a \quad \textbf{(3)}$$

of 20.9°C and air flow parallel to the surface at 1 m/sec. The intrinsic thermal resistance of the fabric,

R_f, is obtained by subtracting the boundary layer air resistance, R_a, from the fabric resistance to heat transfer, R_t, determined by measuring the thermal resistance with the bare hot plate. The set of results for samples taken from the six clothing systems are listed both as clo and thermal resistance values in Table 3.

b. Thermal Manikin Measurements

The thermal resistance of the clothing system, R_t, measured on the thermal manikin is also determined by the power required to maintain a defined temperature gradient, equation 1. In this study, the temperature of the manikin surface and the temperature of the surrounding air were set equal to the temperatures used with the GHP. Air flow was from a frontal direction, i.e., normal to the manikin, maintained at 1 m/sec. Individual heat loss measurements were made for the torso, the left and right legs and the left and right arms. Three trial measurements were taken on the thermal manikin and the mean and standard deviation for each body segment was computed. An example of the calculation of the thermal resistance from the thermal manikin data, employing equation 1, is give in Table 4.

The results, R_t, for the various clothing systems are collected in Table 5 together with the parameters which are required for the later model calculation of the clothing thermal resistance from the GHP fabric resistance, R_f. Some general trends are noted in Table 5. There is good agreement between values for the right and left extremities which lends confidence in the reliability of the measurement technique. However, the torso values are characteristically higher than the resistances determined for the legs and arms. This difference in resistance could be a reflection of the pattern of air flow around segments of the thermal manikin produced by the frontally directed air stream and is also apparent in the measurements of the boundary layer thermal resistance, R_a, determined on the bare thermal manikin.

c. Comparison of Intrinsic Clothing Resistance and Intrinsic Fabric Resistance

To make a direct comparison between the intrinsic clothing thermal resistance, R_{cl}, and the GHP intrinsic fabric resistance, it is necessary to correct the total clothing resistance, R_t, for the boundary layer air resistance, R_a, which is estimated from measurements on the bare thermal manikin and adjusted for the increase in the clothing area as compared to the bare manikin:

$$R_{cl} = R_t - \frac{R_a}{f_{cl}} \tag{4}$$

The clothing area factor, f_{cl}, is always greater than one, and is taken equal to the ratio of the average radius of the clothing segment to the average radius of the thermal manikin segment (see Table 2). As the results of Table 5 show, the value of R_a proves to be a large fraction of the total thermal resistance. The total heat loss from the clothing for a set temperature gradient is the sum of the heat

losses from the individual clothing segments. Therefore, to calculate the average intrinsic clothing thermal resistance, R_{cl}, the clothing segment intrinsic resistances, $R_{cl,i}$, determined according to equation 4, are added as the reciprocals, equivalent to resistances in parallel:

$$\frac{\sum A_i f_{cl}}{R_{cl}} = \sum \left(\frac{A_i f_{cl,i}}{R_{cl,i}} \right) \tag{5}$$

where A_i is the area of the body segment i of the bare manikin and, $f_{cl,i}$, is the clothing area factor of segment i.

Figure 9 shows the results of a linear regression analysis, as a test of the ability to predict the clothing insulation values directly from the GHP measurements. The thermal resistance of four of the six clothing systems cluster about the least squares regression line at low values and the slope of the line is determined mainly by the higher thermal resistances of the Firefighter's Coverall and the Anti-exposure Coverall. The figure includes the 95% confidence limits, which are an estimate of the conditional population mean, and the 95% prediction limits, which indicate the possible spread of an individual predicted value. A summary of some of the parameters from the statistical analysis appears in Table 6. Referring to the data related to Figure 9 in the table, the width of the prediction interval at the mean value of the intrinsic fabric resistance, 0.0918°C-m^2/W, is 0.126°C-m^2/W compared to the range of thermal manikin clothing resistances equal to 0.2313°C-m^2/W, a ratio of 0.54. A suggested criterion for a useful prediction interval would be 20% of the range of measured clothing resistance, 0.046°C-m^2/W. The much larger spread in the prediction interval indicates that the GHP results cannot be used to provide a direct prediction of clothing thermal resistance.

d. Comparison of Measured and Calculated Clothing Thermal Resistances

Models have been developed for predicting the thermal resistance of multilayer clothing as the sum of resistances due to the several fabric layers, the resistances of the air layers between the fabric layers and between the skin and the adjacent fabric layer, and the resistance of the external air boundary layer. In the measurements on the thermal manikin, where only one garment was worn, the expected clothing thermal resistance can be calculated as the sum of the boundary layer air resistance, the interlayer air resistance between the thermal manikin surface and the clothing, and the single fabric resistance from the GHP measurement, corrected for the boundary layer resistance:

$$R_t\,calc = \frac{R_a}{f_{cl}} + R_{al} + \frac{R_f}{f_{cl}} \tag{6}$$

The external boundary layer resistance, R_a, is approximated by measurements on the bare thermal manikin and both R_a and R_f are scaled by the clothing area factor, f_{cl}, to take account of the increase in clothing area compared to the thermal manikin segment.

In the formulation by McCullough (4) the interlayer air resistance, R_{al} is given as:

$$R_{al} = \frac{1}{h_r + k / t_a} \tag{7}$$

where:

R_{al} = thermal resistance of an air layer between the thermal manikin surface and the fabric or between two fabric layers,°C-m^2/W

h_r = radiation heat transfer coefficient, W/°C-m^2

k = thermal conductivity of the air, mm W/°C-m^2

t_a = air layer thickness, mm

The values of the parameters recommended by McCullough, are: h_r = 4.9 W/°C-m^2 and k = 24 mm W/°C-m^2. The air layer thickness between the manikin surface and the inner surface of the clothing was calculated from the clothing radius corrected for the fabric thickness. These values were used to calculate the interlayer air resistances which appear in Table 8. It is evident that the interlayer air resistance is a large component of the total measured resistance but is not a very sensitive function of the air layer thickness, due to the contribution of the radiation coefficient.

An example of the calculation for the thermal resistance of the Disposable Coverall is provided in Table 7 and the comparison of measured and calculated thermal resistances appears in Table 5. The agreement between the calculated and measured values is poor for three of the clothing systems, the Disposable Coverall, Men's Coverall and Aramid Fire Resistant Coverall. The error is somewhat smaller for the TAP Suit and the agreement between calculated and measured values is quite good for the Anti-exposure Suit and Firefighter's Coverall. Values of the average clothing resistance for each of the different clothing items were calculated and a test of the correlation between the calculated and measured values is provided in Figure 10. By including the external boundary layer and interlayer air resistances in the total clothing resistance, the range of the clothing resistances is considerably smaller than the intrinsic fabric resistances represented in Figure 9.

The spread at the mean value of the calculated clothing resistance, R_t= 3.01°C-m^2/W, is 0.125°C-m^2/W for the prediction interval compared to a range of measured resistance values of 0.230°C-m^2/W, a ratio of 0.543. This comparison indicates that the correlation between the measured and calculated clothing resistances is the same as the comparison in Figure 9, which did not include the contribution of the interlayer air resistance. Note, however, that the slope of the least squares line in Figure 10 is close to unity, indicating close agreement between the measured and calculated values. In Figure 9, the slope is significantly higher than unity, indicating that the TM intrinsic resistances are substantially higher than the fabric values. This difference is due to the interlayer air resistance contribution to the thermal manikin intrinsic values.

e. Calculation of Thermal Resistance with Adjusted Interlayer Air Resistance

In an attempt to discover the source of the error responsible for the disparity in the measured and calculated segment resistances, an estimate of the boundary layer air resistance R_a, was back calculated from the above formula, using as input the values of R_f and R_{al}. An example of the calculations is given in Table 8 for the Disposable Coverall. The result, which is listed as $R_a\,eqv$ in Table 8, is only one-fifth the measured boundary layer air resistance, R_a for the torso, and is actually negative for the right leg. Since the interlayer air resistance is the only quantity in equation 6 which is not measured directly, this suggests that the value estimated from equation 5 is much too large for the four clothing systems where there is poor agreement between calculated and measured thermal resistances. The air layer resistance was adjusted by a factor to optimize the agreement between the measured and calculated results for all the segments of a given clothing system. The resulting factors, indicated in Table 9, were 0.62 for Disposable Coverall, 0.60 for Men's Coverall, 0.60 for Aramid Fire Resistant Coverall and 0.69 for Tap Suit. As demonstrated in Table 9, this multiplying factor reduces the error of the calculated values to well under 10% in all cases.

The agreement between the value of the multiplying factor for the three fabric clothing systems suggests that this factor arises from a common cause. Therefore, it seems reasonable to conclude that the air permeability of the fabric allows convection in the interlayer region. The factor for the impermeable TAP Suit is not much higher, probably indicating that thermal convection also occurs in the interlayer air in this case. With the heavier multilayer construction of the Firefighter's Coverall and the Anti-exposure Suit, there is a good fit between the calculated and measured clothing thermal resistance without any need to adjust the interlayer air resistance for convection. However, the agreement in this case could also be due to the high values of R_f which diminish the relative contribution of the interlayer air resistance to the overall clothing resistance.

Average clothing resistances were calculated for the six clothing items from the segment resistances using the adjusted values of the interlayer air resistance, where appropriate. A test of the correlation between the calculated and measured clothing resistances appears in Figure 11 and the statistical parameters for the correlation are summarized in Table 6. At the mean $R_t\,calc = 2.70°C\text{-}m^2/W$, the spread in the prediction limits is $0.045°C\text{-}m^2/W$ and the ratio is 0.19. The narrowed prediction interval is the expected result of optimizing the interlayer air resistance. However, the spread in the prediction interval is still about 20% of the range of R_t values, just within the limit suggested for useful prediction.

2. Determination of the Evaporative Resistance

a. Guarded Hot Plate Measurements

The resistance to evaporative heat transfer, $R_{e,t}$ for a fabric or section of a clothing system, including the boundary layer air resistance, measured on the guarded hot plate is determined by measuring the power, $Q_{e,t}$, required to maintain a defined gradient of water vapor pressure:

$$R_{e,t} = \frac{(P_s - P_a)A}{Q_{e,t}} \tag{8}$$

where:

$R_{e,t}$ = resistance to evaporative heat transfer of a fabric section or clothing system including the boundary layer air resistance, kPa-m²/W

P_s = water vapor pressure at the surface, kPa

P_a = water vapor pressure in the air, kPa

$Q_{e,t}$ = power or heat flow, W

Note, the units for $R_{e,t}$ can be changed from kPa-m²/W, to °C-m²/W by multiplying by the Lewis Ratio, 16.65°C/kPa, for compatibility with the units for thermal resistance. If the units of vapor pressure are mm Hg, the conversion factor is 2.22°C/mm Hg, which with the conversion factor, 0.133 kPa/mm Hg, is equal to the Lewis Ratio.

The evaporative resistance of the fabric or clothing sections was measured on the GHP with flooded surface and with the GHP surface and surrounding air set to the same temperature. The intrinsic evaporative resistance, $R_{e,f}$, was determined by subtracting the air layer evaporative resistance, $R_{e,a}$,

$$R_{e,f} = R_{e,t} - R_{e,a} \tag{9}$$

determined on the bare wetted GHP:

The resistance to evaporative heat transfer is frequently expressed as the vapor permeability index relative to the air permeability index, i_m:

$$i_m = \frac{R_t}{R_{e,t}} \tag{10}$$

Where both R_t and $R_{e,t}$ have units of °C-m²/W. GHP values for $R_{e,t}$ and i_m, as well as $R_{e,f}$ appear in Table 2, for the samples from the four permeable clothing systems. The values of i_m are similar

for all four clothing systems, due to the correlation between the thermal and evaporative resistances. The corresponding values of $R_{e,f}$ are also similar for three of the four clothing systems but the evaporative resistance for the Aramid Fire Resistant Coverall is much higher.

b. Thermal Manikin Measurements

The measurements of evaporative resistance on the thermal manikin were conducted with a temperature, as well as a water vapor pressure gradient. Typical values were as follows: thermal manikin surface temperature, 34.1°C; air temperature, 21.2°C: saturation vapor pressure at the surface temperature, 41.25 mm Hg; air dew point 10.5°C, vapor pressure 9.52 mm Hg and air velocity 1m/sec. There were slight variations in the thermal manikin surface temperature in the different body segments and corresponding variations in the saturation vapor pressure. Note, that the temperature gradient is the same as that used in the thermal resistance measurements.

i_m was calculated automatically from the recorded temperatures by the data acquisition system, air relative humidity and power consumption by the following relation:

$$i_m = \frac{\dfrac{clo\,Q_t}{6.45A} - (T_s - T_a)}{S(P_s - P_a)} \tag{11}$$

where:

Q_t = total heat flow or power due to the combined thermal and vapor gradient, Watts
T_s = temperature of thermal manikin surface, °C
T_a = ambient air temperature, °C
P_s = water vapor pressure at manikin surface, mm Hg
P_a = water vapor pressure in ambient air, mm Hg
S = conversion factor, 2.22°C/mm Hg

The resulting i_m values can readily be converted to the evaporative resistance, $R_{e,t}$, in units of °C-m²/W by means of the relation, equation 9. An example of the calculation of i_m from the thermal manikin data is given in Table 3. Values of $R_{e,t}$ are recorded in Table 10 for the separate clothing segments of each of the four clothing systems. The data exhibits more variability than encountered with the thermal resistances. For the Men's Coverall, the torso value is higher than the evaporative resistance of the arms or legs. In the other three clothing systems, the evaporative resistance of the torso and legs are of similar magnitude and larger than the values for the arm segments. There is also a large degree of variability between the evaporative resistances of the right and left arm, the Men's Coverall being the extreme case. This is a level of variability that was not experienced with the thermal resistances.

c. Comparison of Measured and Calculated Clothing Segment Evaporative Resistances

A comparison with model calculations for the individual clothing segments, based on the wet GHP values of the evaporative resistance, $R_{e,f}$, can be made by summing the various component resistances, adjusted for the clothing area factor:

$$R_{e,t} = \frac{R_{e,a}}{f_{cl}} + R_{e,al} + \frac{R_{e,f}}{f_{cl}} \qquad \textbf{(12)}$$

Since it was not possible to measure the evaporative resistance of the boundary air layer, $R_{e,a}$, directly on the thermal manikin, following McCullough, it was calculated from the convective heat transfer coefficient, h_c and the Lewis Ratio:

$$R_{e,a} = \frac{1}{h_c LR} \qquad \textbf{(13)}$$

where LR has the value 16.65°C/kPa and h_c is determined from the thermal resistance, R_a, measured on the bare manikin:

$$h_c = \frac{1}{R_a} - h_r \qquad \textbf{(14)}$$

The value of the radiation heat transfer coefficient, determined by McCullough, 4.9 W/ °C-m² was used in the present calculations. The dependence of the evaporative resistance on the interior air layer thickness, t_a (mm), was calculated by the relation proposed by McCullough:

$$R_{e,al} = A(1 - \exp - (t_a/B)) \qquad \textbf{(15)}$$

with:

A =0.0334 °C-m²/W
B = 15mm.

An example of the calculation of the evaporative resistance for the Disposable Coverall appears in Table 11. Values of the evaporative resistance calculated from the analytical model are collected in Table 10, and compared with the experimentally measured evaporative resistances. For all four clothing items, the model calculations are in reasonable agreement with the experimental values for the torso, with differences of 20% or less. For the other clothing segments (arms/legs), with the exception of the Men's Coverall, the error in the calculated resistances is generally much larger than 20 % and the calculated values underestimate the experimentally determined evaporative resistances.

d. Possible Causes of Increased Boundary Layer Evaporative Resistance

To determine the source of the error, the effective boundary layer air resistance was calculated from equation 11 by subtracting the contributions of the clothing evaporative resistance and the interlayer

evaporative resistance from the measured evaporative resistance.

$$R_{e,a}eqv = \left[R_{e,t} - \left(R_{e,al} + \frac{R_{e,f}}{f_{cl}}\right)\right] f_{cl} \qquad \textbf{(16)}$$

The results, which are also listed in Table 10, vary widely from the values calculated by means of equation 12, which are based on the thermal resistance determined on the bare thermal manikin. In all cases, the values are larger than the estimate from equation 13, and in some cases larger than the measured clothing evaporative resistance, due to the effect of the clothing area factor in equation 15. Therefore, the effective evaporative resistance is larger than the value used in the modeling.

The disparity, in this case, cannot be ascribed to the interlayer air resistance, which contributes less than 10% of the total resistance, and would be reduced further if convection were taken into account for these permeable clothing systems. It is instructive to make a comparison with the minimum value of the convective heat transfer coefficient, h_c = 4.2 W/°C-m^2, reported by McCullough (4) from measurements on the thermal manikin in still air. Values of h_c, calculated from $R_{e,a}\,eqv$, together with h_c calculated from R_a by equation 13 are compared in Table 12. In almost all cases, $h_c eqv$ is smaller than h_c from R_a, the extreme case being the results for the Firefighter's Coverall. The $h_c eqv$ values are also generally smaller than McCullough's value determined in still air, which conflicts with physical reality.

A clue to a possible cause of the problem is suggested by the observation that the measured evaporative resistances, Table 10, for the torso and the legs are close in value for three of the clothing systems, Men's Coverall, Aramid Fire Resistant Coverall and Firefighter's Coverall. The contrast between the bare and the clothed manikin is suggested by the bulkiness of the Firefighter's coverall, illustrated in Figure 8. If the clothing is bulky, the inside area of the legs might establish contact which would block the flow of air between the legs. Then the barrier to air flow would almost equal in width to that of the torso and the boundary layer evaporative resistance would be comparable. Even for the bare thermal manikin, where the air flow around the legs is relatively unimpeded, the value of $R_{e,a}$ estimated from measurements of R_a are 1.5 times higher for the torso than for the legs. In addition, since the evaporative resistance is proportional to the inverse of the convective heat transfer coefficient, it is more sensitive to the pattern of air flow than the boundary layer thermal resistance, which is the inverse of the sum of both the convection and radiant heat transfer coefficients.

The clothing area factor, f_{cl}, provides some indication of the bulkiness of the clothing. In most cases, f_{cl} for the legs is significantly larger than unity and significantly larger than that of the torso, indicating that the radius of the clothing is expanded beyond the manikin surface. But there is not a clear cut correlation between these values and the values of $R_{e,a}$ for the legs and torso. The most notable exception is the Disposable Coverall, which has a relatively small value of the clothing area factor, but $R_{e,a}$ for each leg is still much smaller than the torso value.

There is another problem which can arise in the measurement of the evaporative resistances. Since the effective evaporative resistances are all larger than predicted, it is also possible that the discrepancies are due to some problems in maintaining a fully wetted surface during the cycle of thermal manikin testing. The lower water vapor pressure would result in a smaller than expected heat loss. This would lead to a higher evaporative resistance when applying equation 10 with the assumption that saturation vapor pressure has been maintained at the manikin surface.

e. Comparison of Measured and Calculated Clothing Evaporative Resistances

Average clothing evaporative resistances were calculated and are compared with the measured evaporative resistances in Figure 12. In spite of the disagreement in the magnitude of the values, there is a reasonable fit to the least squares line, in part, a reflection of the cluster of data in the lower range. The correlation reflects the fact that the measured evaporative resistances for the arm and leg clothing segments are higher than the torso values in all four cases. The width of the prediction interval is 0.225°C-m^2/W, compared to the range of clothing evaporative resistances equal to 0.76°C-m^2/W., a ratio of 0.30. The large width of the prediction interval, despite the close fit of the data to the least squares line, is due primarily to the small sample size and, accordingly, the large standard error of estimate and large Student's t value.

CONCLUSIONS

An initial goal of this study was to determine if the fabric thermal resistances measured on the Guarded Hot Plate could be used to predict directly the clothing resistances measured on the thermal manikin. This elementary approach would be expected to succeed if the fabric is very thick, as is the case with the Anti-exposure Coverall and the Firefighter's Coverall. Otherwise, the measured clothing resistance could be dominated by the boundary layer and interlayer air resistances. However, neither one of these resistances can be measured directly with the clothing in place on the thermal manikin. The interlayer air thermal resistance is calculated by the analytical formula recommended by McCullough, as the sum of the radiative and conductive heat transfer resistances. An examination of the contributions to the measured thermal resistance, suggests that this approach overestimates the interlayer resistance when the fabric is air permeable or thin. The calculation of the evaporative air resistance depends on the values of the boundary layer thermal and evaporative air resistances, which are both estimated from measurements on the bare thermal manikin. However, the air flow around the clothed Thermal Manikin can depart significantly from the pattern with the bare Thermal Manikin. Air flow between the legs is restricted by the clothing bulkiness and contact. This is responsible for the result that the evaporative resistances of the clothing leg segments are far larger than the resistances calculated from measurements on the bare Thermal Manikin.

In summary, the results of this study have been useful in identifying some of the factors which influence the thermal and evaporative resistances of clothing and in demonstrating that corrections to the standard series resistance model of thermal and evaporative clothing resistances are required to improve the accuracy of prediction. It should be straightforward and worthwhile to establish a correlation between the air permeability of fabrics and the factor required to modify the calculated

interlayer air thermal resistance. Accounting for the effect of clothing geometry on the boundary layer thermal and evaporative resistances would be more complicated. A study is required to determine how the clothing bulkiness and clothing segment contacts affect the air flow and, in turn, the boundary layer resistances. The improvements in the uniformity and laminar nature of the air flow in a newly installed test chamber should be helpful in such a study and should also help to minimize or eliminate the differences between the resistances measured, in some cases, for the left and right extremities. By including the corrections for fabric air permeability and clothing geometry in the model calculations, it should be possible to improve the prediction of clothing resistances from the measurements on fabric samples.

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GLOSSSARY

Definition of terms used by McCullough and the ISO standard. Unless otherwise noted all resistances have units of °C-m^2/W.

Note: The first quantity is from McCullough (4); the bracketed quantity is the ISO equivalent.

1. $\boldsymbol{R_a}$ ($\boldsymbol{R_{cto}}$) = apparatus constant (or thermal resistance for the air layer) measured on the bare guarded hot plate.

2. $\boldsymbol{R_t}$ ($\boldsymbol{R_{ct}}$) = total thermal resistance for a fabric or clothing section measured on guarded hot plate; includes series contributions of fabric and boundary layer resistances.

3. $\boldsymbol{R_f}$ ($\boldsymbol{R_{ct} - R_{cto}}$) = intrinsic fabric thermal resistance; the thermal resistance of fabric corrected for boundary layer resistance.

4. $\boldsymbol{R_{e,a}}$ ($\boldsymbol{R_{eto}}$) = apparatus constant (or evaporative resistance for the air layer) measured on the bare, sweating guarded hot plate.

5. $\boldsymbol{R_{e,t}}$ ($\boldsymbol{R_{et}}$) = total evaporative heat transfer resistance of fabric or clothing section measured on sweating guarded hot plate; includes series contributions of fabric and boundary layer evaporative resistances.

6. $\boldsymbol{R_{e,f}}$ ($\boldsymbol{R_{et} - R_{eto}}$) = intrinsic evaporative heat transfer resistance; the evaporative resistance corrected for boundary layer evaporative resistance.

7. $\boldsymbol{i_m}$ = water vapor permeability index; the ratio of the thermal and the evaporative resistances, a dimension less number.

8. $\boldsymbol{R_a}$ = thermal resistance for the boundary layer, measured on the bare Thermal Manikin.

9. $\boldsymbol{R_t}$, ($\boldsymbol{R_{ct}}$) = total thermal resistance for clothing segment or clothing system, as measured on a Thermal Manikin; includes boundary layer, interlayer and clothing series resistances (see 2 above).

10. $\boldsymbol{R_{e,t}}$ ($\boldsymbol{R_{et}}$) = total resistance to evaporative heat transfer for clothing segment or clothing system, as measured on a sweating Thermal Manikin (see 5 above).

11. $\boldsymbol{R_{cl}}$ ***or*** $\boldsymbol{I_{cl}}$ = intrinsic thermal resistance of a clothing ensemble determined by subtracting the boundary layer resistance, modified by the clothing area factor.

12. $R_{e,cl}$ = intrinsic evaporative resistance of a clothing ensemble determined by subtracting the air layer evaporative resistance, modified by the clothing area factor, from $R_{e,t}$.

13. R_{al} = thermal resistance of an air layer between the thermal manikin skin and fabric or between two fabric layers. Estimated using eqn. 12 from McCullough.

14. $R_{e,al}$ = evaporative resistance of an air layer between thermal manikin skin and fabric or between two fabric layers. Estimated using equation 14 from McCullough.

15. f_{cl} = clothing area factor, equal to or greater than unity; the ratio of the area of the clothing segment to the area of the corresponding thermal manikin body segment, taken equal to the ratio of the average radius of the clothing segment and the average radius of the bare thermal manikin body segment.

APPENDIX A

TABLE 1: PARAMETERS FOR THE THERMAL MANIKIN

	Torso	Arms	Legs	Head	Hands & Feet
Total area, 2775 in^2					
Area, in^2	1049	402	737	195	392
Area, %	37.8	14.48	26.56	7.02	14.12
Length, in.	27	23	31	12	
Circumf., in.	38.84	8.73	11.89	16.23	
Radius, r_1, in.	6.185	1.391	1.893	2.585	

From tape coverage of body segments

	Torso	Rt. Arm	Lft. Arm	Rt. Leg	Lft. Leg
Mean a	38.00	11.48	11.33	22.83	22.42
Mean b	33.88	10.73	10.54	14.21	13.96
Mean c	39.17	8.04	7.79	10.04	10.00
Mean	37.01	10.08	9.89	15.69	15.46
Mean circumf., in.	38.84	8.73	8.73	11.89	11.89
Radius, r_2, in.	5.891	1.604	1.574	2.498	2.460
Ratio, r_1/r_2	1.050	0.867	0.884	0.758	0.769

Measurents at three locations; a,b,c

Thermal resistance, bare Thermal Manikin					
R_a °C-m^2/W	0.127	0.105	0.103	0.095	0.105

TABLE 2: CLOTHING GEOMETRICAL FACTORS

	Torso	Rt. Arm	Lft. Arm	Rt. Leg	Lft. Leg
Disposable Coverall	Suit thickness, 0.018 in.				
Radius, in.	7.000	2.506	2.519	3.769	3.797
T.M. Ratio	1.050	0.867	0.884	0.758	0.769
Norm. radius, in.	7.349	2.172	2.226	2.856	2.921
Air layer thick., in.	1.146	0.763	0.817	0.945	1.010
Clothing area factor, f_{cl}	1.188	1.562	1.600	1.509	1.543
Men's Coverall	Suit thickness, 0.014 in.				
Radius, in.	6.181	2.089	2.055	3.427	3.337
T.M. Ratio	1.050	0.867	0.884	0.758	0.769
Norm. radius, in.	6.490	1.810	1.815	2.596	2.567
Air layer thick., in.	0.291	0.405	0.410	0.689	0.660
Clothing area factor, f_{cl}	1.049	1.302	1.305	1.372	1.356
Aramid Coverall	Suit thickness, 0.014 in.				
Radius, in.	6.164	2.318	2.204	3.189	3.098
T.M. Ratio	1.050	0.867	0.884	0.758	0.769
Norm. radius, in.	6.472	2.009	1.947	2.416	2.384
Air layer thick., in.	0.273	0.604	0.542	0.509	0.477
Clothing area factor, f_{cl}	1.046	1.444	1.400	1.276	1.259
Tap Suit	Suit thickness, 0.014 in.				
Radius, in.	7.920	2.594	2.754	4.034	4.121
T.M. Ratio	1.050	0.867	0.884	0.758	0.769
Norm. radius, in.	8.315	2.248	2.434	3.057	3.170
Air layer thick., in.	2.116	0.843	1.029	1.150	1.263
Clothing area factor, f_{cl}	1.344	1.616	1.750	1.615	1.675
Firefighter's Coverall	Suit thickness, 0.147 in.				
Radius, in.	7.270	2.639	2.672	4.108	4.133
T.M. Ratio	1.050	0.867	0.884	0.758	0.769
Norm. radius, in.	7.634	2.288	2.361	3.113	3.180
Air layer thick., in.	1.434	0.882	0.955	1.205	1.272
Clothing area factor, f_{cl}	1.234	1.645	1.697	1.644	1.680
Anti-exposure Coverall	Suit thickness, 0.126 in.				
Radius, in.	7.084	2.627	2.636	3.718	3.517
T.M. Ratio	1.050	0.867	0.884	0.758	0.769
Norm. radius, in.	7.438	2.277	2.329	2.817	2.706
Air layer thick., in.	1.240	0.874	0.926	0.911	0.800
Clothing area factor, f_{cl}	1.203	1.637	1.675	1.488	1.429

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TABLE 3: GUARDED HOT PLATE DATA

	clo	R_t °C-m^2/W	R_f °C-m^2/W	i_m	$R_{e,f}$ °C-m^2/W
Disposable Coverall					
Mean	0.543	0.084	0.036	0.653	0.131
Std. Dev.	0.551	0.085	0.037	0.146	0.024
Coeff. Var	1.014	1.014	1.034	0.224	0.181
Men's Coverall					
Mean	0.517	0.080	0.031	0.590	0.135
Std. Dev.	0.008	0.001	0.001	0.012	0.003
Coeff. Var	0.015	0.010	0.025	0.021	0.022
Aramid Fire Resistant Coverall					
Mean	0.523	0.081	0.032	0.557	0.111
Std. Dev.	0.018	0.004	0.004	0.008	0.006
Coeff. Var	0.035	0.045	0.113	0.014	0.050
Firefighter's Coverall					
Mean	2.023	0.313	0.264	0.383	0.816
Std. Dev.	0.044	0.007	0.007	0.008	0.021
Coeff. Var	0.022	0.022	0.026	0.020	0.026
Tap Suit					
Mean	0.397	0.062	0.013		
Std. Dev.	0.018	0.003	0.003		
Coeff. Var	0.046	0.049	0.231		
Anti-exposure Suit					
Mean	1.410	0.219	0.170		
Std. Dev.	0.035	0.005	0.005		
Coeff. Var	0.025	0.021	0.027		
Bare Guarded Hot Plate					
Mean	0.310	0.049		0.767	0.063
Std. Dev.	0.006	0.001		0.006	
Coeff. Var	0.018	0.018		0.008	

TABLE 4: CALCULATION OF THERMAL AND EVAPORATIVE RESISTANCES FROM THERMAL MANIKIN MEASUREMENTS

Disposable Coverall, Dry

	Torso	Rt. Arm	Lft. Arm	Rt. Leg	Lft. Leg
T_a °C	20.88	20.88	20.88	20.88	20.88
T_s °C	34.55	34.69	34.73	34.8	34.75
Q, W	41.56	9.58	9.01	18.17	17.26
A, m^2	0.677	0.130	0.130	0.238	0.238
R_t °C-m^2/W	0.223	0.187	0.199	0.182	0.191
clo	1.44	1.20	1.28	1.17	1.23

Disposable Coverall, Wet

	Torso	Rt. Arm	Lft. Arm	Rt. Leg	Lft. Leg
$T_{a,}$ °C	21.16	21.16	21.16	21.16	21.16
Dpt, °C	10.51	10.51	10.51	10.51	10.51
P_a mm Hg	9.52	9.52	9.52	9.52	9.522
T_s °C	34.07	32.76	33.67	33.68	34.14
P_s mm Hg	41.27	37.05	39.38	39.39	39.93
Q, W	155.16	31.15	36.15	89.22	81.46
A, m^2	0.68	0.13	0.13	0.24	0.24
clo	1.44	1.20	1.28	1.17	1.23
I_m	0.561	0.568	0.675	0.876	0.810
R_t °C-m^2/W	0.397	0.329	0.295	0.208	0.236

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TABLE 5: MEASURED PARAMETERS FOR CALCULATION OF CLOTHING THERMAL RESISTANCE

	Torso	Rt. Arm	Lft. Arm	Rt. Leg	Lft. Leg
Disposable Coverall					
R_f from GHP = 0.0354 °C-m^2/W					
R_{a1} °C-m^2/W	0.174	0.162	0.164	0.168	0.170
R_t meas, °C-m^2/W	0.225	0.192	0.200	0.186	0.194
R_a/R_t meas	0.564	0.548	0.514	0.508	0.544
R_t calc, °C-m^2/W	0.311	0.245	0.244	0.255	0.262
Err. %	37.84	27.68	21.85	36.87	35.02
Men's Coverall					
R_f from GHP = 0.0354 °C-m^2/W					
R_{a1} °C-m^2/W	0.120	0.137	0.137	0.158	0.157
R_t meas, °C-m^2/W	0.222	0.172	0.176	0.195	0.202
R_a/R_t meas	0.573	0.614	0.585	0.485	0.522
R_t calc, °C-m^2/W	0.272	0.234	0.233	0.250	0.258
Err. %	22.51	36.54	32.16	28.36	27.47
Aramid Fire Resistant Coverall					
R_f from GHP = 0.0324 °C-m^2/W					
R_{a1} °C-m^2/W	0.117	0.153	0.149	0.147	0.144
R_t meas, °C-m^2/W	0.232	0.176	0.173	0.202	0.207
R_a/R_t meas	0.548	0.600	0.596	0.468	0.510
R_t calc, °C-m^2/W	0.270	0.242	0.239	0.246	0.253
Err. %	16.22	37.69	38.03	21.76	22.51
Tap Suit					
R_f from GHP = 0.0124 °C-m^2/W					
R_{a1} °C-m^2/W	0.186	0.165	0.171	0.174	0.176
R_t meas, °C-m^2/W	0.253	0.181	0.207	0.197	0.207
R_a/R_t meas	0.503	0.583	0.498	0.479	0.509
R_t calc, °C-m^2/W	0.290	0.233	0.232	0.240	0.247
Err. %	14.88	28.63	12.04	21.64	19.00
Anti-exposure Suit					
R_f from GHP = 0.1704 °C-m^2/W					
R_{a1} °C-m^2/W	0.176	0.167	0.168	0.168	0.164
R_t meas, °C-m^2/W	0.468	0.326	0.336	0.356	0.362
R_a/R_t meas	0.272	0.324	0.307	0.266	0.291
R_t calc, °C-m^2/W	0.424	0.344	0.344	0.322	0.333
Err. %	-9.42	5.72	2.36	-9.57	-7.82
Firefighter's Coverall					
R_f from GHP = 0.2644 °C-m^2/W					
R_{a1} °C-m^2/W	0.177	0.161	0.164	0.172	0.174
R_t meas, °C-m^2/W	0.496	0.371	0.392	0.409	0.421
R_a/R_t meas	0.256	0.284	0.263	0.231	0.251
R_t calc, °C-m^2/W	0.494	0.386	0.381	0.390	0.394
Err. %	-0.36	3.91	-2.91	-4.60	0.291

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TABLE 6: SUMMARY OF STATISTICAL PARAMETERS FOR CORRELATION TESTS

Correlation of TM Intrinsic Resistance and Fabric Intrinsic Resistance: Figure 9

X, mean fabric resist	0.0918	DF	6
del Y1, meas. resist range	0.2313	t value	2.776
del Y2, pred resist width	0.1262	Syx	0.0210
del Y2/del Y1	0.5450	t*Syc	0.0631

Clothing Thermal Resistance, Measured/Calculated Correlation: Figure 10

X, mean calc resist	0.3055	DF	6
del Y1, meas. resist range	0.2300	t value	2.776
del Y2, pred resist width	0.1250	Syx	0.0208
del Y2/del Y1	0.543	t*Syc	0.0625

Thermal Resistance Calculated with Adjusted Values of Interlayer Air Resistance: Figure 11

X, mean calc resist	0.2700	DF	6
del Y1, meas. resist range	0.2347	t value	2.776
del Y2, pred resist width	0.0449	Syx	0.0075
del Y2/del Y1	0.191	t*Syc	0.0250

Evaporative Resistance, Measured/Calculated Correlation: Figure 12

X, mean calc resist	0.5328	DF	4
del Y1, meas. resist range	0.7562	t value	4.304
del Y2, pred resist width	0.2250	Syx	0.0213
del Y2/del Y1	0.300	t*Syc	0.1130

Explanation of terms:
DF, degrees of freedom
t value, coordinate in Student's t distribution
Syx, standard error of estimate
Syc, estimated error of conditional mean
t*Syc, weighting factor in calculation of prediction interval

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Table 7: Sample Calculation of Thermal Resistance Disposable Coverall

	Torso	Rt. Arm	Lft. Arm	Rt. Leg	Lft. Leg
Manikin radius, in.	6.185	1.391	1.391	1.893	1.893
Dsp Cvl, radius, in.	7.345	2.171	2.225	2.855	2.920
Air layer thick., in.	1.160	0.780	0.834	0.962	1.027
Suit thick. 0.018 in.					
Corr. for suit thick.	1.142	0.762	0.816	0.944	1.009
Air layer resist.	0.174	0.162	0.164	0.168	0.170
R_t calc, °C-m²/W	0.311	0.245	0.244	0.255	0.262
R_t meas, °C-m²/W	0.225	0.192	0.200	0.186	0.194
Err. %	37.84	27.68	21.85	36.87	35.02

Sample Calculation, Torso Data

$$R_a/f_{cl} + R_{a1} + R_f/f_{cl} = R_t$$

$$0.127/(7.345/6.185)+0.174+0.0354/(7.345/6.185)$$

$$0.311\ m^2\text{-}C/W$$

GHP results	clo	R_t °C-m²/W	R_f °C-m²/W
Dsp Cvl	0.52	0.0840	0.0354
Bare Plate	0.31	0.0486	

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TABLE 8: SAMPLE CALCULATION OF THERMAL RESISTANCE WITH ADJUSTED VALUES OF THE INTERLAYER AIR RESISTANCE DISPOSABLE COVERALL

	Torso	Rt. Arm	Lft. Arm	Rt. Leg	Lft. Leg
R_f from GHP = 0.0354 °C-m²/W					
Manikin, R_a, m²-°C/W	0.127	0.105	0.103	0.095	0.105
Manikin radius, in.	6.185	1.291	1.291	1.893	1.893
Dsp Cvl, radius, in.	7.345	2.171	2.225	2.855	2.920
Air layer thick., in.	1.160	0.780	0.834	0.962	1.027
R_{a1} °C-m²/W	0.174	0.162	0.164	0.168	0.170
1. R_t meas, °C-m²/W	0.225	0.192	0.200	0.186	0.194
2. R_t calc, °C-m²/W	0.311	0.245	0.244	0.255	0.262
Error %	37.84	27.68	21.85	36.87	35.02
R_{a1} eqv, °C-m²/W	0.026	0.016	0.028	-0.009	0.001
Adj. R_a (0.62*R_{a1})	0.104	0.119	0.135	0.088	0.101
3. R_t recalc, m²-°C/W	0.245	0.184	0.182	0.191	0.197
Error %	1.92	-0.82	-1.85	0.46	0.31

Sample Calculation, Torso Data:

R_a eqv	(0.225-0.0354*6.185/7.345-0.174)*7.345/6.185 = 0.0258
Adj. R_a (0.62*R_{a1})	(0.225-0.0354*6.185/7.345-0.174*0.62)*7.345/6.185 = 0.104
R_t recalc	0.127*6.185/7.345+0.0354*6.185/7.345+0.174*0.62 = 0.245

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Arial12, print 90%

TABLE 9: THERMAL RESISTANCES CALCULATED WITH ADJUSTED VALUES OF THE INTERLAYER AIR RESISTANCE

	Torso	Rt. Arm	Lft. Arm	Rt. Leg	Lft. Leg
Disposable Coverall					
1. R_t meas, °C-m^2/W	0.225	0.192	0.200	0.186	0.194
2. R_t calc, °C-m^2/W	0.311	0.245	0.244	0.255	0.262
Error %	37.84	27.68	21.85	36.87	35.02
R_a °C-m^2/W, Bare T.M.	0.127	0.105	0.103	0.095	0.105
R_a eqv, °C-m^2/W	0.025	0.016	0.028	-0.009	0.001
Adj. R_a (0.62*R_{a1})	0.104	0.119	0.135	0.088	0.101
3. R_t recalc, °C-m^2/W	0.245	0.184	0.182	0.191	0.197
Error %	8.54	-4.29	-9.22	2.46	1.62
Men's Coverall					
1. R_t meas, °C-m^2/W	0.222	0.172	0.176	0.195	0.202
2. R_t calc, °C-m^2/W	0.272	0.234	0.233	0.250	0.258
Error %	22.51	36.54	32.16	28.36	27.47
R_a °C-m^2/W, Bare T.M.	0.127	0.105	0.103	0.095	0.105
R_a eqv, °C-m^2/W	0.075	0.018	0.023	0.019	0.03
Adj. R_a (0.62*R_{a1})	0.125	0.094	0.101	0.106	0.115
3. R_t recalc, °C-m^2/W	0.223	0.180	0.178	0.187	0.195
Error %	0.78	4.68	1.01	-4.12	-3.54
Aramid Coverall					
1. R_t meas, °C-m^2/W	0.232	0.176	0.173	0.202	0.207
2. R_t calc, °C-m^2/W	0.270	0.242	0.239	0.246	0.253
Error %	16.22	37.69	38.03	21.76	22.51
R_a °C-m^2/W, Bare T.M.	0.127	0.105	0.103	0.095	0.105
R_a eqv, °C-m^2/W	0.085	-0.001	0.001	0.035	0.044
Adj. R_a (0.62*R_{a1})	0.134	0.095	0.091	0.110	0.116
3. R_t recalc, °C-m^2/W	0.226	0.182	0.181	0.190	0.198
Error %	-2.73	3.88	4.73	-6.08	-4.16
Tap Suit					
1. R_t meas, °C-m^2/W	0.253	0.181	0.207	0.197	0.207
2. R_t calc, °C-m^2/W	0.290	0.233	0.232	0.240	0.247
Error %	14.88	28.63	12.04	21.64	19.00
R_a °C-m^2/W, Bare T.M.	0.127	0.105	0.103	0.095	0.105
R_a eqv, °C-m^2/W	0.054	-0.008	0.033	0.003	0.017
Adj. R_a (0.62*R_{a1})	0.131	0.081	0.133	0.090	0.108
3. R_t recalc, °C-m^2/W	0.250	0.195	0.191	0.200	0.206
Error %	-1.22	7.66	-7.63	1.56	-0.73

Arial 12, column width 9, print 95%

TABLE 10: EVAPORATIVE RESISTANCE PARAMETERS AND COMPARISON OF MEASURED AND CALCULATED VALUES

	Torso	Rt. Arm	Lft. Arm	Rt. Leg	Lft. Leg
Disposable Coverall					
$R_{e,f}$ from GHP = 0.066 °C-m²/W					
$R_{e,a}$ °C-m²/W	0.316	0.209	0.200	0.170	0.209
$R_{e,a1}$ °C-m²/W	0.029	0.024	0.025	0.027	0.028
$R_{e,a}$ eqv, °C-m²/W	0.364	0.467	0.202	0.209	0.261
$R_{e,t}$ meas, °C-m²/W	0.391	0.341	0.181	0.209	0.239
$R_{e,t}$ calc, °C-m²/W	0.350	0.188	0.180	0.183	0.206
Error, %	-10.38	-44.92	-0.58	-12.23	-14.00
Men's Coverall					
$R_{e,f}$ from GHP = 0.072 °C-m²/W					
$R_{e,a}$ °C-m²/W	0.316	0.209	0.200	0.170	0.209
$R_{e,a1}$ °C-m²/W	0.013	0.017	0.017	0.023	0.022
$R_{e,a}$ eqv, °C-m²/W	0.322	0.289	0.332	0.394	0.402
$R_{e,t}$ meas, °C-m²/W	0.389	0.274	0.304	0.363	0.372
$R_{e,t}$ calc, °C-m²/W	0.383	0.217	0.210	0.200	0.230
Error, %	-1.63	-20.75	-30.82	-45.00	-38.24
Aramid Fire Resistant Coverall					
$R_{e,f}$ from GHP = 0.081 °C-m²/W					
$R_{e,a}$ °C-m²/W	0.316	0.209	0.200	0.170	0.209
$R_{e,a1}$ °C-m²/W	0.012	0.021	0.020	0.019	0.018
$R_{e,a}$ eqv, °C-m²/W	0.345	0.290	0.319	0.421	0.399
$R_{e,t}$ meas, °C-m²/W	0.419	0.260	0.285	0.412	0.400
$R_{e,t}$ calc, °C-m²/W	0.392	0.208	0.206	0.216	0.249
Error, %	-6.61	-19.99	-27.67	-47.58	-37.81
Firefighter's Coverall					
$R_{e,f}$ from GHP = 0.076 °C-m²/W					
$R_{e,a}$ °C-m²/W	0.316	0.209	0.200	0.170	0.209
$R_{e,a1}$ °C-m²/W	0.031	0.026	0.027	0.029	0.030
$R_{e,a}$ eqv, °C-m²/W	0.604	0.411	0.620	0.794	1.352
$R_{e,t}$ meas, °C-m²/W	1.136	0.738	0.840	0.974	1.287
$R_{e,t}$ calc, °C-m²/W	0.903	0.615	0.593	0.595	0.607
Error, %	-20.54	-16.63	-29.47	-38.92	-52.88

Arial 12, column width 9, print 90%

TABLE 11: SAMPLE CALCULATION OF EVAPORATIVE RESISTANCE DISPOSABLE COVERALL

	Torso	Rt. Arm	Lft. Arm	Rt. Leg	Lft. Leg
Manikin, R_a °C-m^2/W	0.127	0.105	0.103	0.095	0.105
h_c W/°C-m^2	3.168	4.788	5.002	5.876	4.788
$R_{e,a}$ °C-m^2/W	0.316	0.209	0.200	0.170	0.209
Manikin, radius, in.	6.185	1.291	1.291	1.893	1.893
Dsp Cvl, radius, in.	7.345	2.171	2.225	2.855	2.920
Air layer thick., in.	1.160	0.780	0.834	0.962	1.027
$R_{e,a1}$ °C-m^2/W	0.029	0.024	0.025	0.027	0.028
$R_{e,t}$ meas, °C-m^2/W	0.350	0.188	0.180	0.183	0.206
$R_{e,t}$ calc, °C-m^2/W	0.391	0.341	0.181	0.209	0.239
Error, %	-10.38	-44.92	-0.58	-12.23	-14.00

Sample Calculation, Torso Data

$h_c = 1/R_a - h_r = 1/0.127 - 4.7 = 3.168$ W/°C-m^2

$R_{ea} = 1/h_c = 1/3.168 = 0.316$ °C-m^2/W

$R_{e,a}/f_{cl} + R_{e,a1} + R_{e,f}/f_{cl} = R_{e,t}$

$0.316/(7.345/6.185)+0.029+0.066/(7.345/6.185)$

$= 0.350$ °C-m^2/W

GHP results	i_m	R_t °C-m^2/W	$R_{e,t}$ °C-m^2/W	$R_{e,f}$ °C-m^2/W
Dsp Cvl	0.650	0.084	0.129	0.066
Bare Plate	0.7667	0.0486	0.063	

File: dspcvl4, Block: n48..u74

Table 12: Equivalent Values of Convective Heat Transfer Coefficient, h_c (W/^{o}C-m^2)

	Torso	Rt. Arm	Lft. Arm	Rt. Leg	Lft. Leg
Disposable Coverall					
h_c eqv	2.749	2.143	4.957	4.791	3.838
h_c (from R_a)*	3.168	4.788	5.002	5.876	4.788
Men's Coverall					
h_c eqv	3.103	3.466	3.016	2.537	2.490
h_c (from R_a)*	3.168	4.788	5.002	5.876	4.788
Aramid Coverall					
h_c eqv	2.901	3.453	3.135	2.378	2.505
h_c (from R_a)*	3.168	4.788	5.002	5.876	4.788
Firefighter's Coverall					
h_c eqv	1.657	2.435	1.613	1.260	0.740
h_c (from R_a)*	3.168	4.788	5.002	5.876	4.788

* Calculated from equation 14.

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APPENDIX B

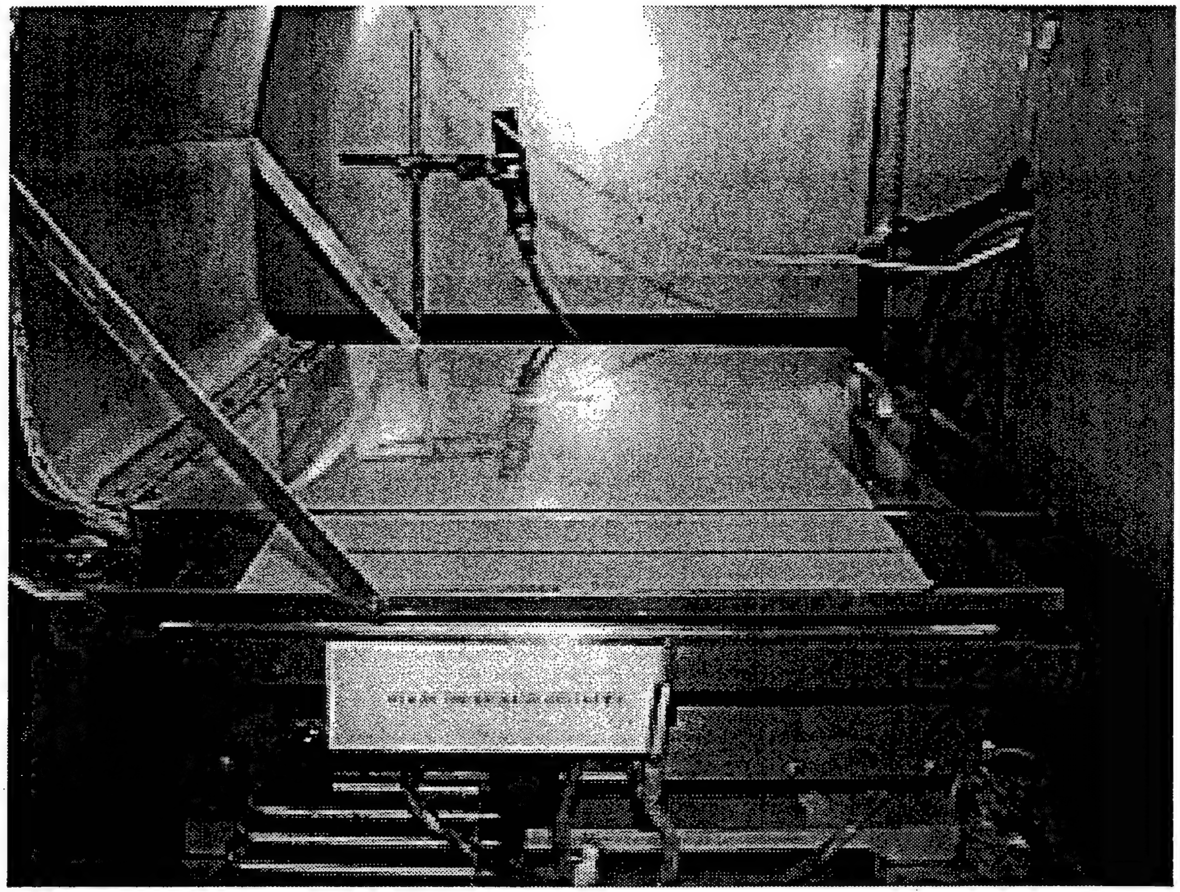


Figure 1. Sweating Guarded Hot Plate

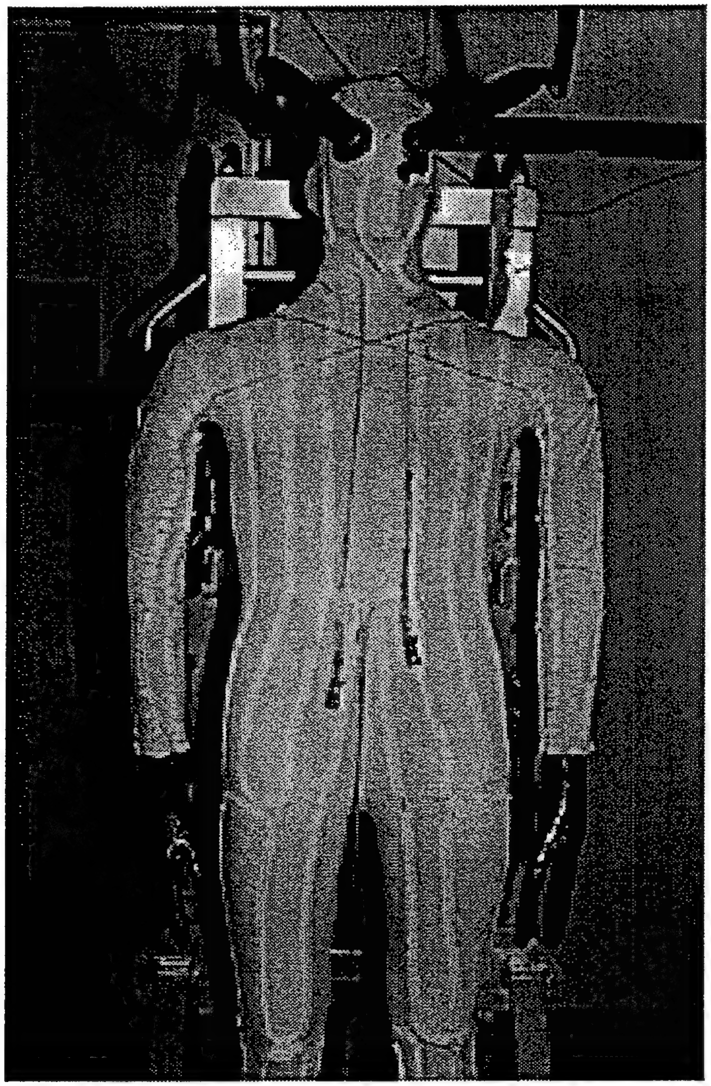


Figure 2. Thermal Manikin With Knit Fabric Sweating Skin

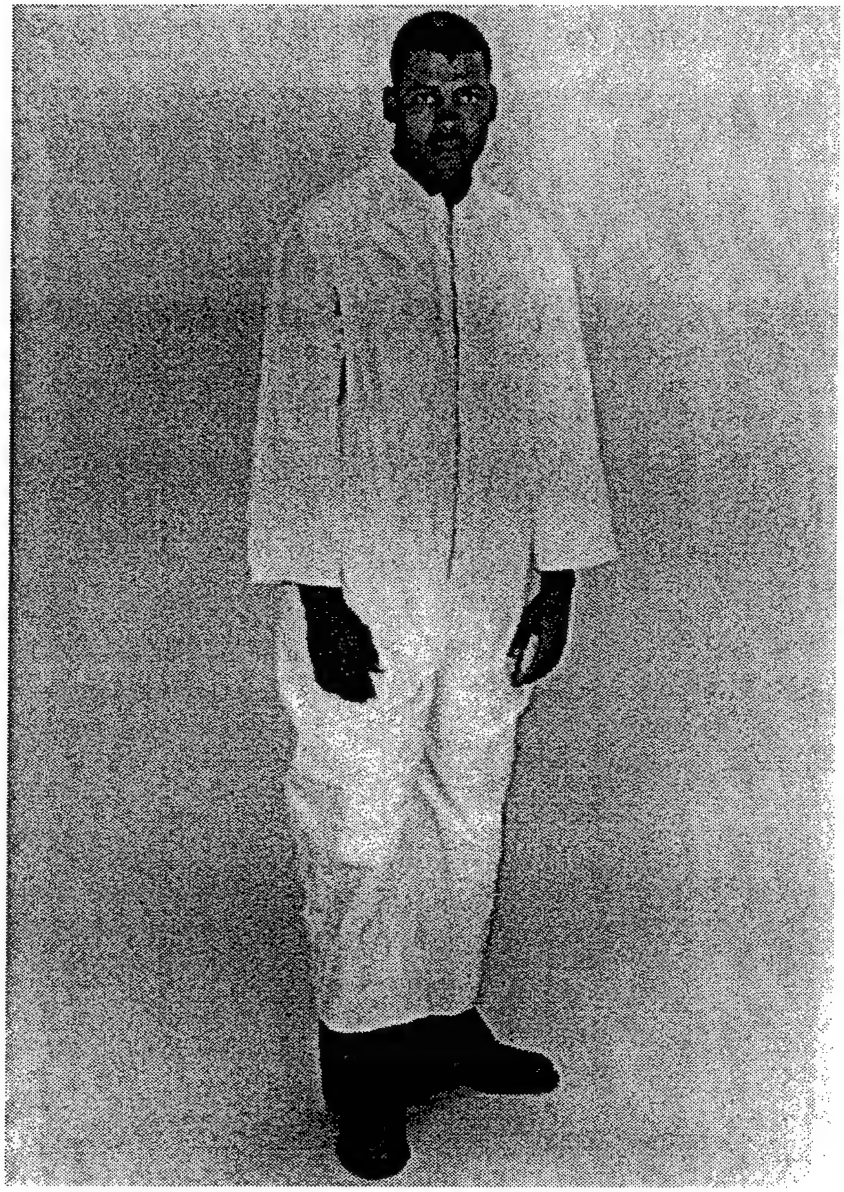


Figure 3. Disposable Coverall

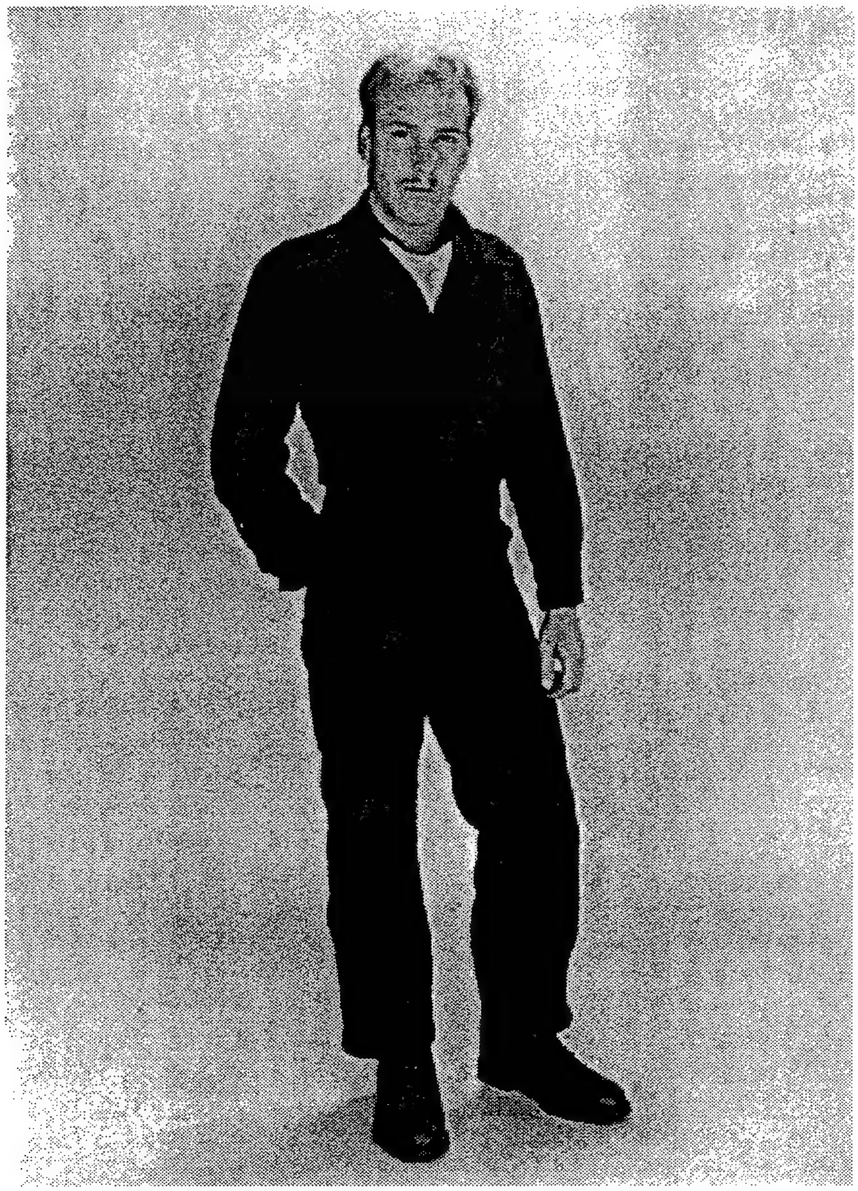


Figure 4. Men's Coverall

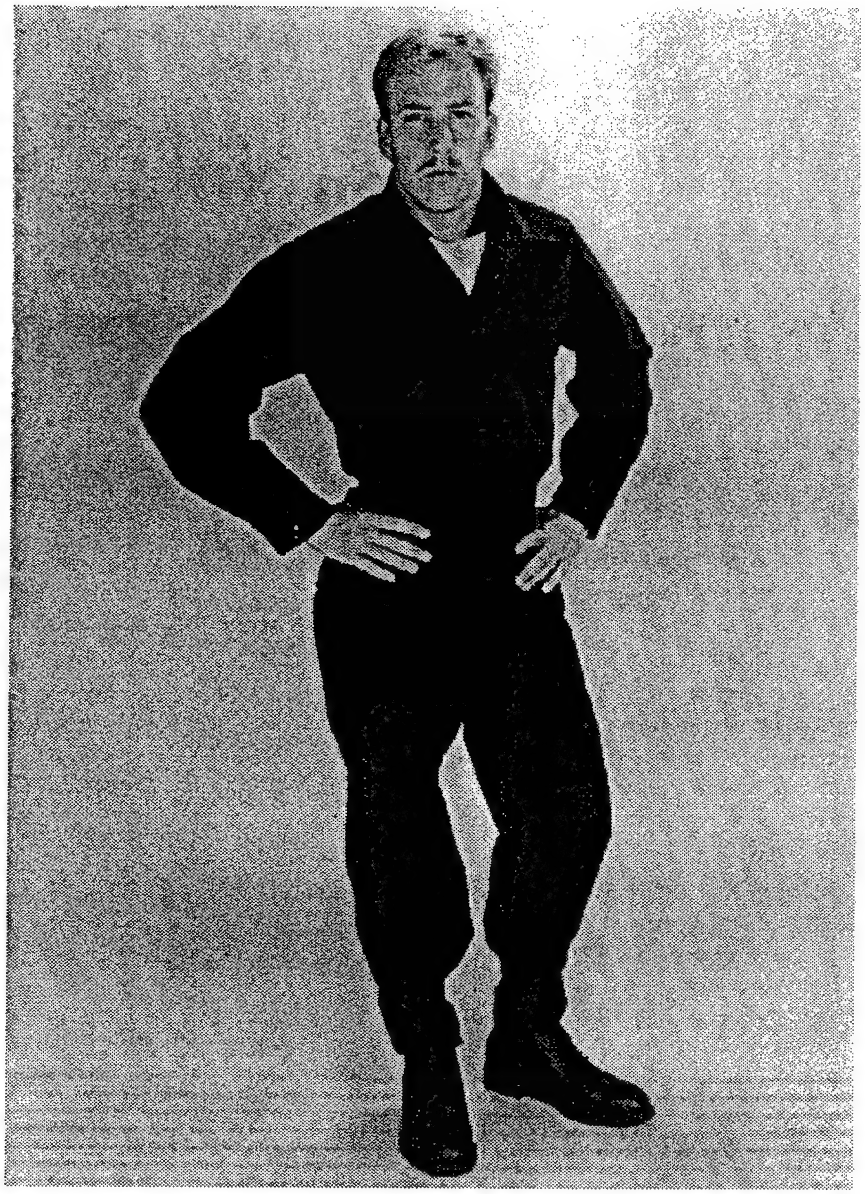


Figure 5. Aramid Coverall

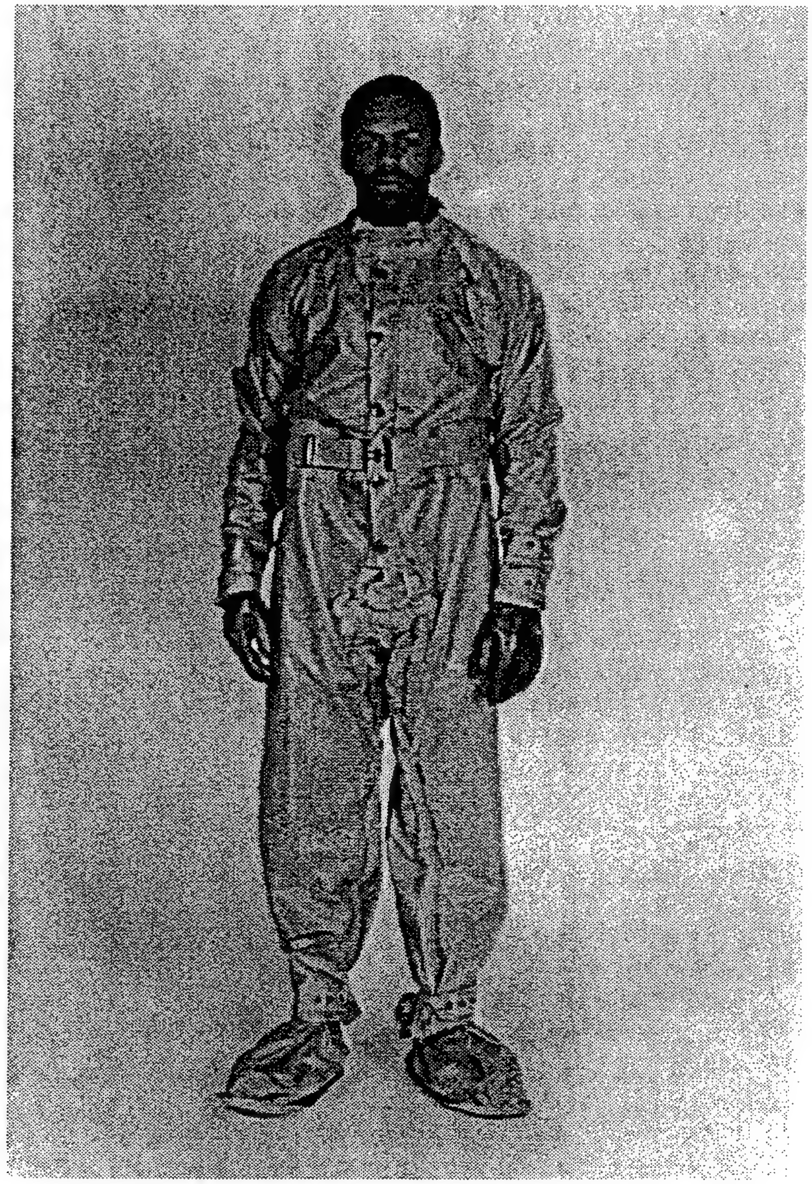


Figure 6. TAP Suit

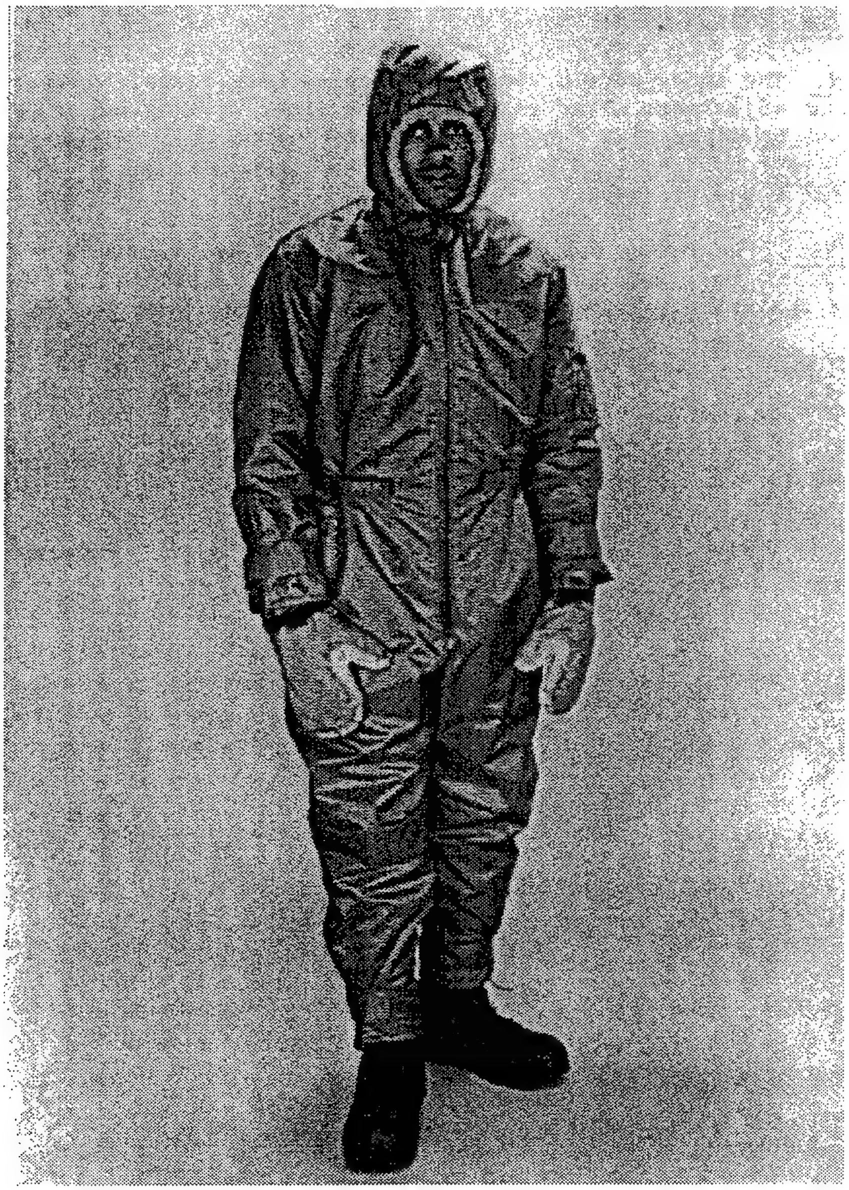


Figure 7. Anti-exposure Coverall

Figure 8. Firefighter's Coverall

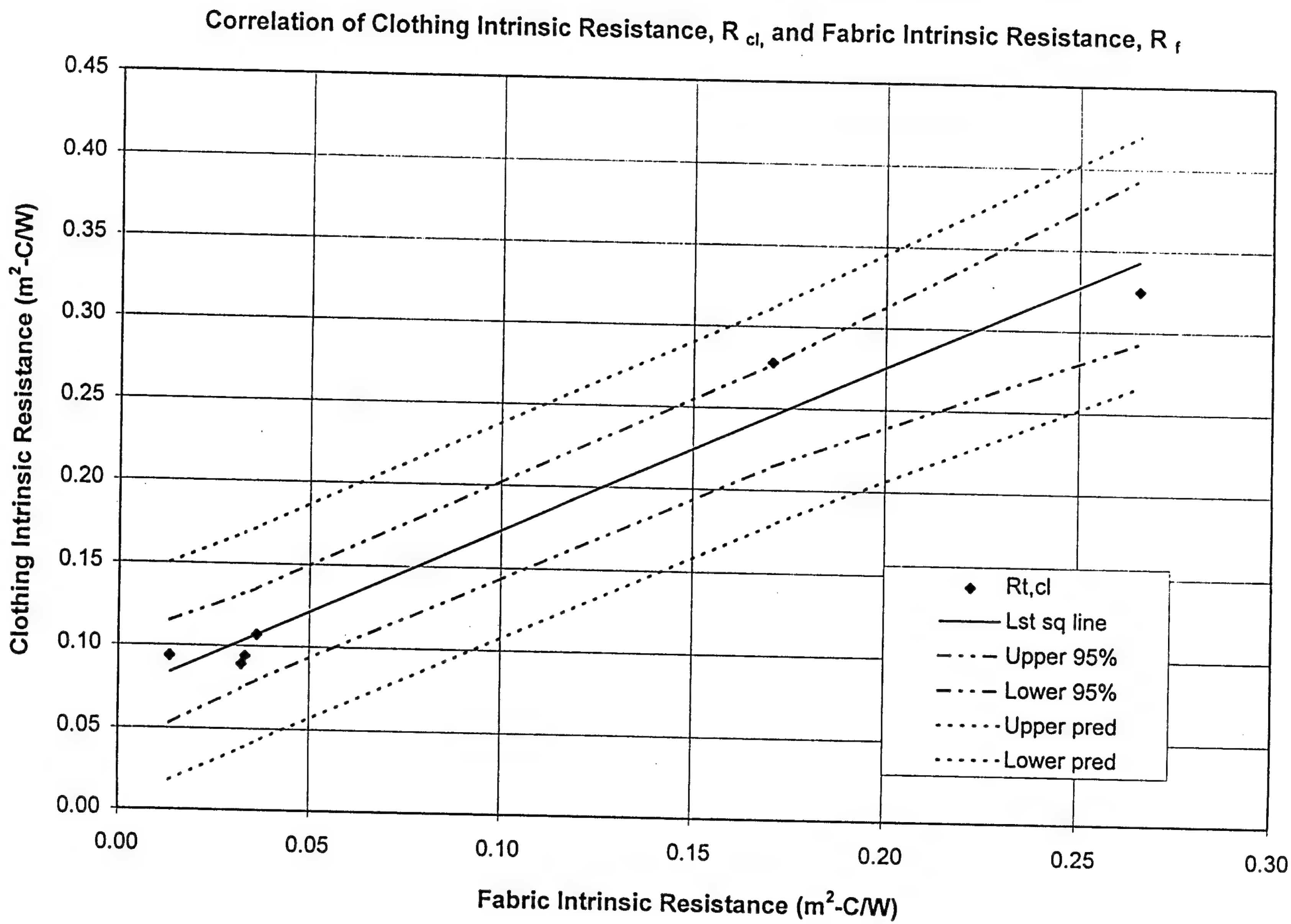

Correlation of Clothing Intrinsic Resistance, R cl, and Fabric Intrinsic Resistance, R f
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Clothing Intrinsic Resistance (m2-C/W)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Fabric Intrinsic Resistance (m2-C/W)
Rt,cl
Lst sq line
Upper 95%
Lower 95%
Upper pred
Lower pred

Figure 9

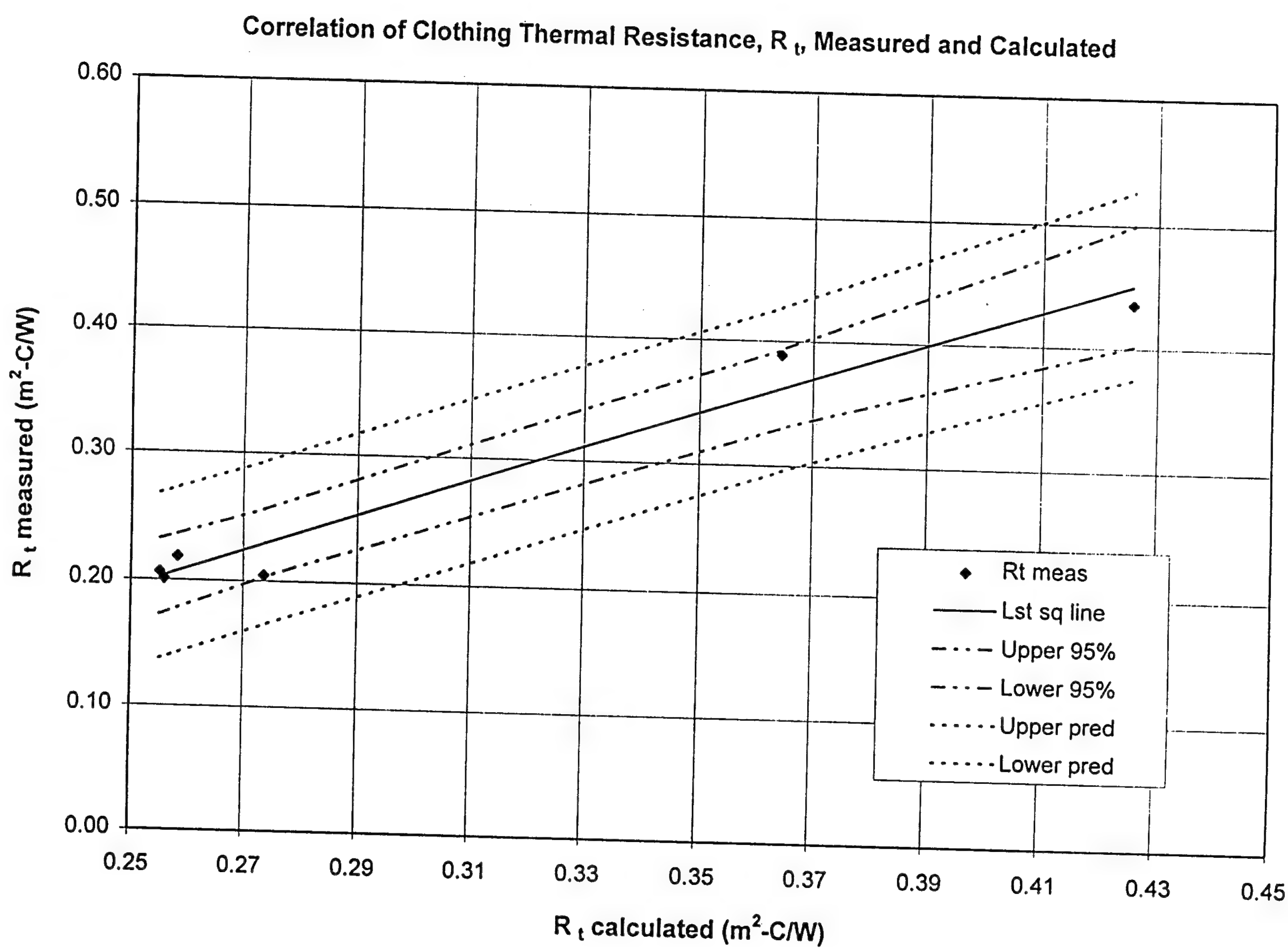
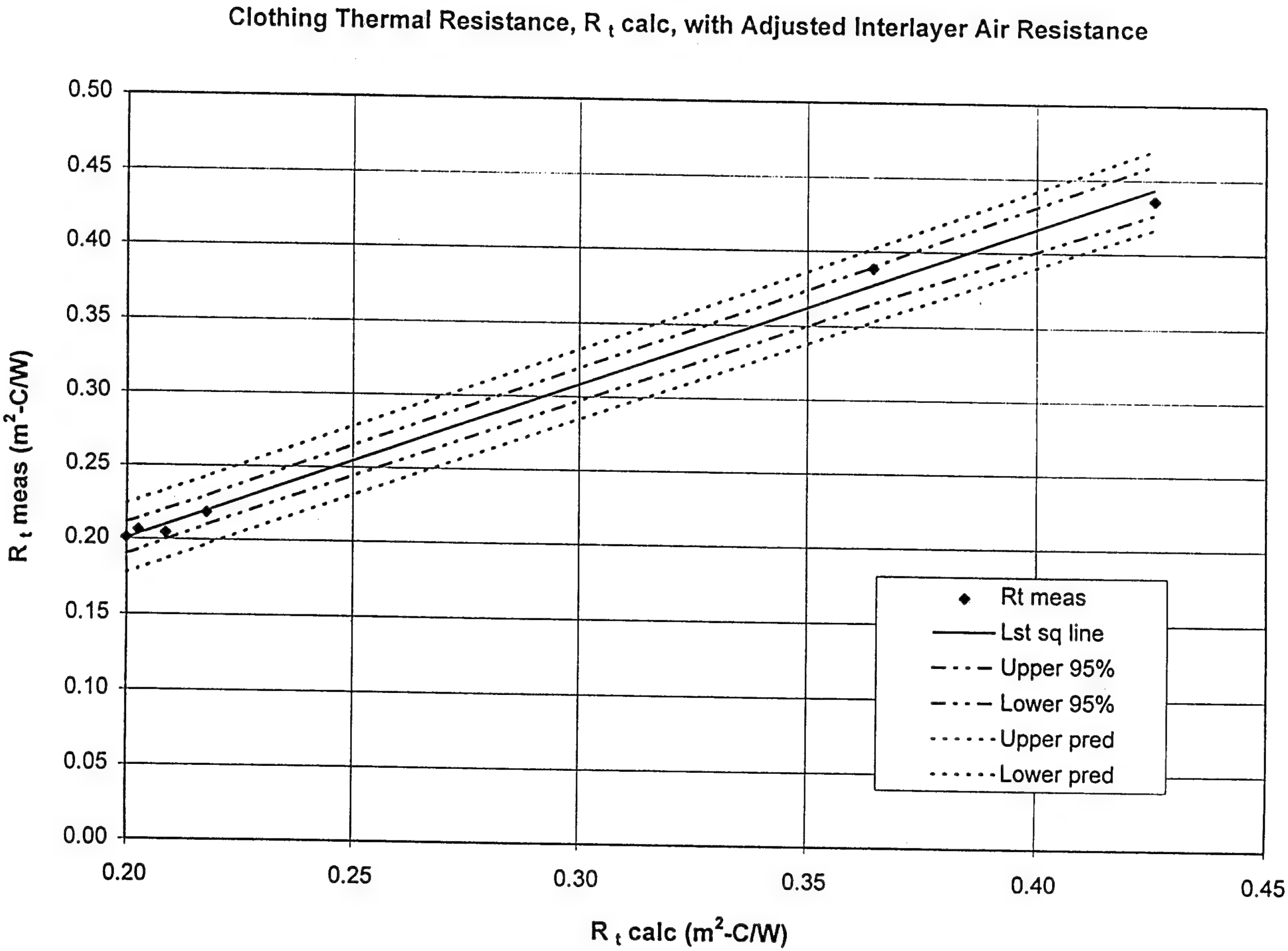
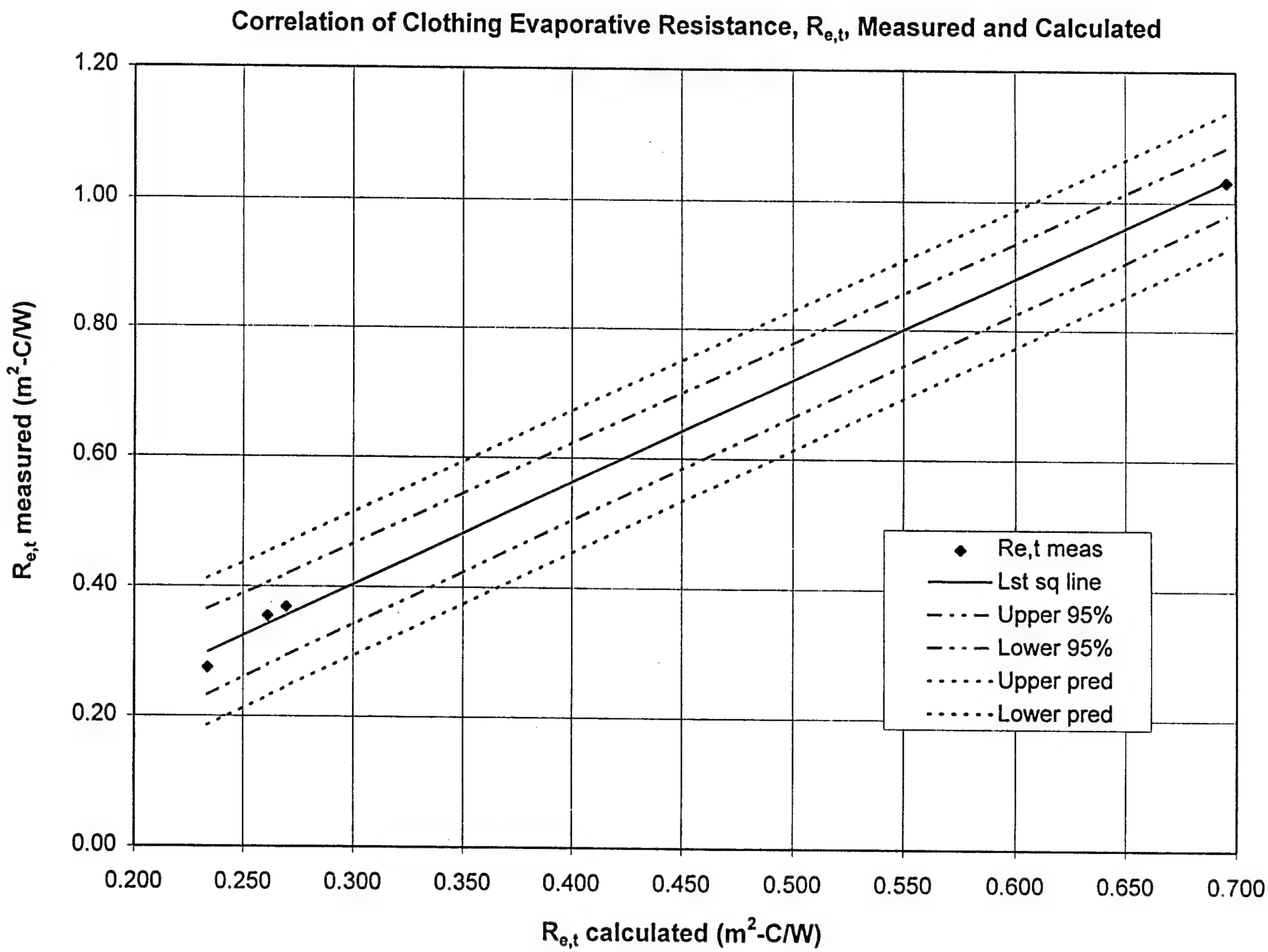

Correlation of Clothing Thermal Resistance, R t, Measured and Calculated
0.60
0.50
0.40
0.30
0.20
0.10
0.00
R t measured (m2-C/W)
0.25
0.27
0.29
0.31
0.33
0.35
0.37
0.39
0.41
0.43
0.45
R t calculated (m2-C/W)
Rt meas
Lst sq line
Upper 95%
Lower 95%
Upper pred
Lower pred

Figure 10



Clothing Thermal Resistance, R t calc, with Adjusted Interlayer Air Resistance
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
R t meas (m2-C/W)
0.20
0.25
0.30
0.35
0.40
0.45
R t calc (m2-C/W)
Rt meas
Lst sq line
Upper 95%
Lower 95%
Upper pred
Lower pred

Figure 11.



Correlation of Clothing Evaporative Resistance, $R_{e,t}$, Measured and Calculated
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.200
0.250
0.300
0.350
0.400
0.450
0.500
0.550
0.600
0.650
0.700
$R_{e,t}$ measured (m^2-C/W)
$R_{e,t}$ calculated (m^2-C/W)
Re,t meas
Lst sq line
Upper 95%
Lower 95%
Upper pred
Lower pred

Figure 12

Record and Disclosure of Invention
Department of the Navy

Walter B. Teal, Jr.
Navy Clothing and Textile Research Facility
Natick, MA

1 October 1997

Invention: PUMPED FLUID SYSTEM FOR TRANSFER OF BODY HEAT

1. General Purpose. The invention is a passive heat transfer device that is capable of maintaining heat flow to the hands and fingers to provide protection from frostbite at temperatures below -40 F and is also capable of being applied for the protection of other extremities, including the feet, ears and exposed skin surfaces..

2. Background. A significant problem in providing cold weather protection is the difficulty of protecting the fingers and other body extremities and exposed skin surfaces from the danger of frostbite. The problem of protecting the fingers from frostbite has received considerable attention and will be used as the example of the function and application of the invention. The conventional approach to cold weather protection for the hands and fingers is the use of well insulated mittens or gloves. However, very thick insulation interferes with the ability to perform manual tasks and insulation alone may not be adequate to protect the fingers at temperatures below -40 F. Various devices have been developed to provide additional heating to the fingers ref. (1-6). In particular, battery powered gloves and heating elements have been designed ref. (4,5), but this approach is limited by the battery capacity, the weight of the power source, especially if mounted on the individual gloves and the development of hot spots. Another approach uses the body as a source of heat, in one example the upper arms ref. (6,7). Heat is transferred to the fingers using heat pipes in which the working fluid is vaporized at the body temperature and heat is released by condensation at the lower temperature of the fingers. However, this approach is not capable of supplying the minimum 5 Watts of heat that is necessary to prevent vasoconstriction and ensuing frostbite.

3. Description and Operation. The example chosen to illustrate the invention is the heated glove illustrated in Figure 1 (Note: Numbers in parentheses refer to numbered items in the attached figure). In this application, the PUMPED FLUID SYSTEM FOR TRANSFER OF BODY HEAT provides a means of extracting heat from the large area of the torso and transferring the heat efficiently to warm the hands and fingers. The design is capable of supplying as a minimum, the 5 Watts of auxiliary heating that is required to prevent vasoconstriction and the accompanying danger of frostbite to the fingers. The invention, Figure 1, consists of (1) an Exotemp Shirt®, (2) a battery powered pump motor, (3) an expansion chamber, (4) gloves. The Exotemp Shirt (1) is an undergarment which contains a network of thin, flexible plastic tubing to transfer heat from the torso and arms to the working fluid. The Exotemp Shirt is available as an off-the-shelf item and is only cited as an example of the type of arrangement which maximizes the torso area as a source of body heat. An alternative arrangement is a bladder with a pattern of heat sealed channels to direct the fluid flow. The working fluid may be water, but other fluids, such as ethyl alcohol, might be

preferred since the lower viscous resistance would permit the use of a lower power pump. The tubing in the Exotemp Shirt is continuous with the tubing in the glove (4) to allow the heated fluid to be circulated directly to tubing that is embedded in the indivdual glove fingers, as shown in Figure 1. Several different glove designs are possible. Among the options are a quick disconnect on the back of the glove and at the wrist of the undergarment sleeve to permit donning of the glove after dressing in the undergarment. Another option is to use a glove which is an integral part of the undergarment but has an open palm to facilitate insertion of the fingers. A flap closure could be used for the palm, but would not be necessary, if the heated glove is meant to be an insert into an outer insulated glove.

4. Advantages. The new feature of the invention is the concept of using certain body areas as a continuous source of heat in conjunction with the use of a pumped fluid to provide a high, continuous level of heat transfer from the source to the exposed body extremities that require protection from the effects of exposure to extreme cold. In the application cited as an example, heat is supplied to the hands and fingers equal to 5 Watts, as a minimum, to prevent vasoconstriction and frostbite at temperatures below -40 F. This approach overcomes the limitation of heat pipes as the method of heat transfer. In the heat pipe approach, the working fluid is the small amount of vapor produced at the temperature of the body source and vapor transport is driven by the small difference in vapor pressure between the body source and the hand. Although this mechanism is dependent on the difference in the temperature of the body heat source and the cooler body extremity, e.g. the fingers, it is not capable of being externally driven to provide greater amounts of heating, when required. The present invention, utilizing a pumped heat transfer fluid is capable of delivering a larger amount of heat to the fingers due to the direct circulation of the pumped heated fluid to the tubing in the fingers of the glove. In addition, with the use of a temperature sensor in the fingers, the pump speed could be controlled to provide a higher volumetric flow rate to the fingers on demand. The use of an undergarment design of the Exotemp type is capable of drawing heat from the large surface area of the torso and arms. This insures that the circulating fluid will be maintained at body temperature, therefore, providing the maximum efficiency in heat transfer between the torso and the hands and fingers.

5. Alternatives. The invention has been described with reference to a preferred example. It is not intended that the invention be limited by the disclosure of the presently preferred application. Instead it is intended that the invention be defined by the means, and by their obvious equivalents, which are set forth in the following claims:

1. A system for transferring body heat to gloves to prevent frostbite of fingers in conditions of exposure to extreme cold. The use of the Exotemp Shirt is an example of an undergarment design with embedded tubing to extract heat from the torso and arms. The heat transfer fluid is circulated to the gloves with a small, efficient pump. It is claimed that the system disclosed in this invention is capable of delivering the 5 Watts of heat, as a minimum, that is required to prevent frostbite at temperatures below -40 F. The pump may be coupled with a sensor in one of the glove fingers and with feedback circuitry to vary the flow rate and heat delivery in response to changes in demand. Other designs, in addition to that pictured and discussed in this disclosure, are possible. Design optimization could incorporate variations in the

amount of tubing, tubing placement and tubing design to improve heat transfer efficiency and comfort of the undergarment. Future improvements in power sources and pump designs, which would offer reductions in size and weight, are readily incorporated in this invention. Various options exist for the glove design to improve heat transfer to the fingers, ease of donning and to reduce the bulk and increase manual dexterity when wearing the heated glove with or without a separate outer glove.

2. A system for transferring body heat to socks to prevent frostbite of feet from extreme cold and the accumulated moisture due to trapped sweat. The body heat can be extracted from the thighs and legs, with a network of small, flexible tubing embedded in long-john underwear and pumped to the tubing in the socks to heat the toes. Alternatively, the torso can be used as the body source of heat, as in example 1 above. The connection can be made in a manner which is convenient for dressing and undressing by using a quick disconnect to couple the tubing in the underwear and socks.

3. A system for transferring body heat to protect other parts of the body which are difficult to protect by passive insulation alone under extreme cold weather conditions. Areas such as the ears, nose and head, in analogy to the disclosure for protecting the fingers, could be heated by fluid pumped to flexible tubing embedded in ear, nose and/or head covering.

4. A system for transferring body heat to protect exposed skin surfaces from extreme cold, especially the face, by pumped fluid circulation to a face mask containing embedded tubing for heat transfer to the face.

5. A system for transferring body heat to a mask covering the mouth and nose to heat inhaled air as a means of protecting the lungs and throat from damage under conditions of extreme cold. The air is heated by pumped fluid circulation to a face mask constructed of layers of loose woven or nonwoven fabric in which tubing carrying the heat transfer fluid is embedded. The mask acts as a filter which serves to heat the inhaled air.

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2.	4543671	10/1985	Monk
3.	5035003	1/1991	Rinehart
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5.	4950868	8/1990	Moss et al.
6.	5269369		Faghri

Journal Publication

7. A. Faghri, D.B. Reynolds, P. Faghri, *Mechanical Eng.* **vol. no.**, 71 (1989).

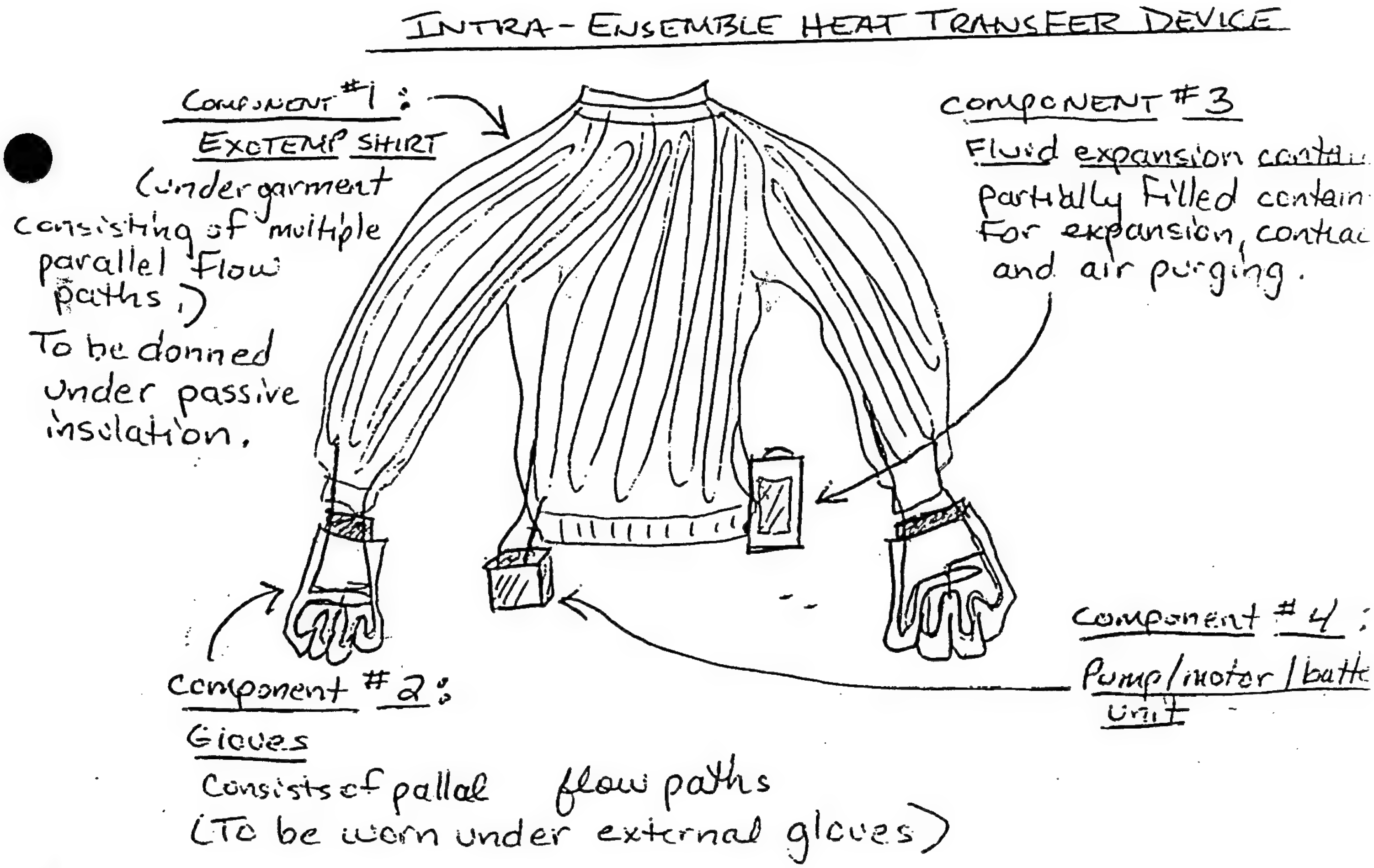

Figure 1: Pumped Fluid System for Transfer of Body Heat

GC-TR-97-3117-030

Wear Test of Two Commercial Utility Uniforms and Three Utility Uniforms using Commercial Fabrics

Mark J. Buller **Debra Meyers**

22 December 1997

Prepared For:
U.S. Navy Clothing and Textile Research Facility
P.O. Box 59
Natick, MA 01760-0001
Under Contract No. N00014-95-D0048/0004, Task No. 3117-030

Prepared By:
GEO-CENTERS, INC.
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Newton Center, MA 02159

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Executive Summary

The Navy Clothing and Textile Research Facility (NCTRF) investigated five candidate utility uniforms as possible replacements to the current utility (dungaree) uniform. The candidates were planned to overcome longstanding complaints of poor fit, pockets that are not useful, poor durability, and unattractive appearance. Testing was conducted in two phases: Phase I tested two commercial off-the-shelf uniforms currently available from uniform rental companies. Phase II tested commercially available materials made to Navy patterns.

Phase I - Commercial Off-the-Shelf

Over 460 male and female subjects were issued two uniforms to wear in place of their current utility uniform for six months. Three test sites were used, the U.S.S. Monongahela, U.S.S. Nimitz, U.S.S. Stennis. User preference surveys were collected at the three and six month points.

The candidate uniforms were as follows: *Configuration A* :4 oz 65% polyester/35% cotton poplin medium blue shirts & 7 oz 65% polyester/35% cotton twill navy blue pants; *Configuration B*: 4 oz 65% polyester/35% cotton chambray shirts & 14.5 oz 100% cotton denim pants.

Approximately 150 subjects completed surveys for both periods. Both uniforms were found to be acceptable in the areas of fit, design and utility, durability, comfort, and overall. However, for almost all areas, Uniform B (4 oz 65% polyester/35% cotton chambray shirts 14.5 oz 100% cotton denim pants) was preferred.

Phase II - Modified Commercial

1278 male and female subjects were each issued the three uniforms to wear in place of their current utility uniform for six months. Approximately 50% of the subjects were located in Norfolk, VA and the other 50% in San Diego, CA. The subjects were crew members of one of 15 participating ships. Demographic and sizing information were collected when the uniforms were issued. Subjects were instructed to wear each uniform in rotation, changing each uniform as it needed laundering. Representatives from NCTRF visited the test subjects at three and six months. At these points, comprehensive fit and user preference surveys were issued and completed by the subjects.

The candidate uniforms were as follows: *Configuration A*: 4 oz 100% cotton chambray shirts & 11.3 oz 100% cotton denim pants; *Configuration B*: 4 oz 100% cotton chambray shirts & 14.5 oz 100% cotton denim pants; *Configuration C*: 4 oz 65% polyester/35% cotton poplin shirts & 7 oz 65% polyester/35% cotton twill pants.

In total, 501 subjects completed surveys for all periods. The poly/cotton shirt (Shirt C) was found to be acceptable in all test areas. In comparison, the chambray shirt (Shirt A/B) was found to be uncomfortable in hot conditions, and after laundering was hard to maintain its appearance. When compared to the current uniform, Shirt C was favored slightly less. Thus, it was concluded that neither of the shirts would be adequate to replace the current shirt.

The pants, however, were found to be acceptable in all areas, and liked better than the current dungarees. There were significant problems for the females for the twill trouser (Pant C): approximately 50% of all female subjects could not be fit. This, however, was most probably due to an incorrect sizing tariff at issue.

It is recommended that the current shirt be kept, and that the current dungarees be replaced by any of the three pant configurations. Given that the fit problems of Pant C among the women are attributable to an inventory problem rather than to a pattern problem, it is likely to be the best choice for replacement to the current dungaree pants. The logic behind this recommendation is as follows: female subjects preferred Pant C to either Pants A or B; while male subjects preferred Pants A & B to C, they found Pant C to be acceptable and preferred them to the current dungarees pants. Given the females' clear preference for Pant C and that males found them to be acceptable replacements for the current uniform, Pant C appears to be an acceptable replacement.

Introduction

The current Navy Utility Uniform, commonly called the *dungaree* uniform, has been with the Navy for almost 60 years. The current uniform consists of a light blue chambray shirt and dungaree style pants with *bell bottoms* and patch style pockets. The pants have been maligned for being baggy and ill fitting and their pockets have been criticized for their lack of utility.

In order to improve the current utility uniform, The Navy Clothing and Textile Research Facility (NCTRF) investigated the possibility of replacing the current utility uniform. Toward this end, a market investigation was conducted of commercial uniforms. It showed that the two most common types are comprised of poplin shirts and twill pants, or jeans and a work shirt. The poplin shirts are comprised of 4oz. polyester/cotton, and twill pants are made of 7 oz. polyester/cotton fabric. The jeans most commonly consist of 14.5oz 100% cotton denim material with straight legs, scoop style front pockets, and patch back pockets and are usually one of the three commercial brands, Levi®, Wrangler®, or Lee®. The shirts generally consist of a western style 4 oz. 100% cotton shirt.

In order to determine the acceptability of a new utility uniform, NCTRF conducted a user test of several candidates. These candidates were selected from commercially available work uniforms, and were comprised of a work shirt combined with either chino pants or jeans. The six month test was designed so that the candidate uniforms were worn in lieu of the current dungaree uniform. In an effort to subject the candidates to the most severe conditions possible, the test participants were selected from *flight deck crew*, *boatswain's mates* and *engineering ratings*.

All test participants were issued each configuration and were required to wear them with the same frequency. All garments were subject to normal shipboard laundering procedures. At the three month and at the end (6 months) of the test, a questionnaire was administered to measure several factors, including, but not limited to: fit, durability and preference of the test garments (and the differences between men and women, in particular).

The testing program was conducted in two phases. They are described below.

Phase I - Commercial Off-the-Shelf (COTS) Uniforms

Phase I consisted of commercial uniform configurations available through uniform rental companies. They were comprised of the following materials:

Configuration A : 4 oz 65% polyester/35% cotton poplin medium blue shirts
7 oz 65% polyester/35% cotton twill navy blue pants

Configuration B:	4 oz 65% polyester/35% cotton chambray shirts 14.5 oz 100% cotton denim pants

Two vendors were chosen to supply garments: Red Kap Industries from Nashville, TN, and Southern Apparel, from Robersonville, NC. Red Kap was selected because all of their garments are domestically produced. They produced the shirts for Configurations A and B and the pants for Configuration A. Southern Apparel produced the pants used for Configuration B (Note: *Off-the-shelf* commercial jeans were not included in this test due to problems associated with stone washing and/or enzyme washing or treatment to promote fading and degradation of the cloth. Also, some off-the-shelf jeans are produced with rivets which is a hazard).

Phase I was conducted onboard the USS John Stennis and USS Monongahela in Norfolk, VA and onboard the USS Nimitz in Bremerton, WA.

Phase II - Modified commercial (Navy patterns with commercial fabrics)

Phase II garments were made from current Navy patterns using commercial fabrics. This approach was used in order to examine the new candidate fabrics without having also to evaluate the fit of a new design. The test garments were produced by current Navy suppliers of clothing (i.e., shirts were produced by Seagoing Uniform Co. from Marshville, NC; twill pants were produced by Southern Apparel from Robersonville, NC). The candidate test uniform configurations were as follows:

Configuration A:	4 oz 100% cotton chambray shirts 11.3 oz 100% cotton denim pants
Configuration B:	4 oz 100% cotton chambray shirts 14.5 oz 100% cotton denim pants
Configuration C:	4 oz 65% polyester/35% cotton poplin shirts 7 oz 65% polyester/35% cotton twill pants

Phase II was conducted onboard nine ships/commands on the East Coast and eight ships/commands on the West Coast. They were as follows:

East Coast	West Coast
USS George Washington (CVN-73)	USS Comstock (LSD-45)
USS Jacksonville (SSN-699)	USS Boxer (LHD-4)
USS Emory S. Land (AS-39)	USS McKee (AS-41)
USS Wasp (LHD-1)	USS LaJolla (SSN-701)
USS Arctic (AOE-8)	USS Constellation (CV-64)

East Coast	West Coast
USS Briscoe (DD-977)	CVW-2
NAS, Norfolk	SIMA, San Diego
SIMA, Norfolk	NAS North Island
VRC-40	

In order to assess the performance and acceptability of these new uniforms, they were subjected to six months of shipboard tests occurring on both coasts. These tests were designed to measure both objective and subjective data regarding the *fit*, *design*, *utility*, and *durability* of the new uniforms. The results of both phases of this wear test are presented in this report.

Phase 1 - Commercial Off-the-Shelf Uniforms

Methodology

Design

A within-subject design was used to allow each subject to wear each uniform. By allowing each test participant to wear both uniform types, situational factors such as weather, job classification and geographic location were controlled.

Subjects

Four hundred and sixty two male and female subjects from three ships were originally issued both uniforms.

Procedures

The test period was six months. The two test uniforms were worn in place of subjects' current dungaree uniform. The test uniforms were worn in rotation, and were laundered as necessary.

Uniforms were initially issued based upon self-reported sizes. Garments were not issued until both the fitter and the subject felt that they were the proper size. An issue sheet (see Appendix A) was completed for each subject, detailing their self-reported size, the sizes of the garments issued and demographic information. The best fit possible was provided.

Test participants were visited at the three and six month points in the test, and were issued a *Wear Test Questionnaire* (see Appendix B). The questionnaire was the same for the mid- and end-points. The mid- and end-point data collections were used to determine how well the garments stood up over time. The user questionnaires were designed to obtain information on: fit, design, utility, durability and comfort.

Wear Test Questionnaires

Fit and Preference questionnaires were used to elicit test participants' opinions about the shirts and pants in this phase of the study. The questioners were divided into five sections, each addressing the following factors: *fit*, *design* and *utility*, *durability*, *comfort*, and *overall acceptance*.

Fit was characterized by asking test participants to rate the garment along several dimensions. For example, *Fit* was rated on a five-point scale, ranging from *Dislike Very Much* to

Like Very Much. In addition, five-point scales were used to evaluate the *length* and *type of fit* of the garments.

The *Design* and *Utility* sections measured the degree to which the design of the garments were acceptable to the wearers.

The *Durability* section allowed test participants to rate the durability of the garments and detail any problem areas.

The *Comfort* section measured test participants' ratings of overall comfort, and comfort in hot and cold environments for each garment.

Results

Demographics of Respondents

Table 1 shows the number of surveys returned for each phase of the test. Approximately 150 subjects completed all three phases of the study. The difference in the number of respondents at each data collection point is a result of attrition of test participants, and of a difference in response rate at each data collection point (i.e., some subjects provided responses at only one of the two data collections).

Researchers involved in similar survey work - where test items are initially issued and the experimenters return at a later date to conduct surveys - assume that they will encounter an attrition rate of approximately 50%. In this study, because there were two data collections (and therefore, an additional chance for attrition) and the subjects who were used for the final analysis had to have completed surveys at **both** the mid and end points, it was expected that this number would be lower than 50%.

In deed, the final group of subjects selected for analysis was approximately 33% of the original group. This is an acceptable attrition rate given the two data collections, and that the analysis included only those subjects who were present for both data collections.

TABLE 1

Returned Surveys

Survey Point	N
Issue	462
Mid	359
End	187
All Phases	150

Demographic Information

Twenty six percent of all those who completed surveys were women. Table 2 lists the number of subjects from each ship who were issued garments. As can be seen, over 50% of the respondents were from the U.S.S. Stennis.

TABLE 2

Number of Responses by Ship

Ship	N	%
Monongahela	76	16.5
Nimitz	118	25.5
Stennis	268	58.0

Analysis of Shirt and Pants Data

The analyses of the shirt and pants data were conducted separately, with each being subjected to approximately 20 different analyses. Due to the large numbers of comparisons being made, the *Bonferoni correction* was applied to all analyses. The Bonferoni correction reduces the chances of obtaining false positive results (i.e., saying there is a difference in the data, when there is actually no difference). The following formula was used to implement the correction.

$$\begin{aligned} \text{Adjusted Significance Level} &= \text{Alpha Level/Number of Analyses} \\ &= 0.05 / 20 \\ &= 0.0025 \end{aligned}$$

Except where stated, all scaled questions were subjected to split-plot Analyses of Variance (ANOVA), with garment type (Uniform A, Uniform B) and Data Collection Point (Midpoint, Endpoint) serving as within-subject variables, and gender serving as a between-subject factor.

Shirts

Fit of Shirts

Scale:

Dislike Very Much	Dislike Moderately	Neither Like nor Dislike	Like Moderately	Like Very Much
1	2	3	4	5

TABLE 3

Mean Fit Ratings for Shirts

	Shirt A	**Shirt B**
	$\bar{x}$	$\bar{x}$
Overall Fit	3.80	4.09
Across Shoulders	3.83	4.04
Chest	3.81	4.05
Sleeve	3.61	3.89
Neck	3.67	3.96
Waist	3.76	4.00

Table 3 shows the mean ratings of *Fit* for each shirt. All ratings were positive, indicating that, in general, the fit of both shirts was liked moderately. The mean fit rating for Shirt B was significantly higher for all areas ($F(1,142) \geq 10.41$ $p<0.0025$ in all cases).

In addition, the *description of fit* mean rating was consistent for both shirts. Both shirts received an average rating of nearly 3.4 for all areas questioned. The data suggest an almost even split between shirts being rated as *neither too tight nor too loose* and *moderately loose*. The preference of fit data from Table 3 suggests that a slightly baggier fit was acceptable to test participants.

The mean ratings of sleeve length was, on average, rated as being *just right* and did not vary between shirts. However, when considering gender, the female mean rating was significantly higher ($F(1,142)=11.57$, $p<0.0025$) than was the males' ($\bar{x}$=3.07, 3.39 for males and females, respectively). This suggests that a number of female subjects found the length of the shirt sleeves *slightly too long*. The overall length mean ratings, again, clustered around *just right* (3.0) and were consistent for both shirts, regardless of data collection or gender.

Design and Utility of Shirts

Table 4 lists the mean ratings for both shirts for all *design and utility* questions.

TABLE 4

Design and Utility Ratings

		Shirt A	Shirt B
		$\bar{x}$	$\bar{x}$
Overall Look	(1=Really Dislike, 5=Really Like)	3.24	3.76
Suitability to Job	(1=Very Unsuited, 5=Very Suited)	3.26	3.42
Ease of Pocket Use	(1=Very Difficult, 5=Very Easy)	3.66	3.74

The mean ratings for *overall look* differed significantly by garment ($F(1,140)=24.48$, $p<0.0025$). Shirt A, in general, was rated 3.24 (fair), while Shirt B received an average rating of 3.76 (*like*). Thus, test participants were neutral about the overall look of Shirt A, while they had a preference for Shirt B.

With respect to suitability to performing their jobs, test participants rated both shirts positively. Ratings for both shorts fell between *OK* and *somewhat suited*. There was no statistical difference between shirt ratings.

Pockets were found to be *fair* to *somewhat easy* to use, with the mean ratings for both shirts falling above 3.5. There was no significant difference between shirt ratings.

Durability

Table 5 lists the mean ratings for *durability* and *maintenance of appearance*.

TABLE 5

Durability Ratings

		Shirt A	Shirt B
		$\bar{x}$	$\bar{x}$
Durability	(1=Not Durable, 5=Very Durable)	3.74	3.83
Maintenance of Appearance	(1=Very Poorly, 5=Very Well)	3.73	3.71

Both shirts received positive mean durability ratings. There were no significant differences between shirt ratings. Similarly, both shirts received positive mean ratings for maintaining their appearance after laundering.

Comfort

Table 6 lists the mean ratings for comfort (*Overall* and *in hot and cold conditions*) of each shirt.

Scale:

Very Uncomfortable	Uncomfortable	Acceptable	Comfortable	Very Comfortable
1	2	3	4	5

TABLE 6

Comfort ratings in Hot and Cold Conditions and Overall

	Shirt A	**Shirt B**
	$\bar{x}$	$\bar{x}$
Overall	3.70	3.90
When Hot	3.30	3.50
When Cold	3.55	3.77

Overall, both shirts received a mean rating above 3.5 (between *acceptable* and *comfortable)*. When in hot conditions, both were rated as acceptable; however, Shirt B's rating was significantly higher ($F(1,131)=11.45$, $p<0.0025$), suggesting that Shirt B was seen as more comfortable in hot conditions. Similarly, Shirt B's mean rating in the cold was also significantly higher than was Shirt A's ($F(1,136)=13.80$, $p<0.0025$). Taken together, these data suggest that Shirt B is more comfortable than Shirt A. Although the *overall* comfort ratings did not differ significantly, this same pattern was revealed - Shirt B received a higher rating than did Shirt A.

Overall Rating

The overall rating given to each shirt is based upon the following scale:

Scale:

Very Poor	Poor	Fair	Good	Very Good
1	2	3	4	5

The mean *overall ratings* for each shirt were positive, between *fair* and *good* ($\bar{x}$=3.54, 3.84 Shirts A and B, respectively). These mean ratings differed significantly (F(1,139)=14.87, P<0.0025), suggesting that, overall, test participants favored Shirt B over Shirt A.

Pants

Fit of Pants

Table 7 lists the mean fit preference rating for each pant for each fit area.

Scale:

Dislike Very Much	Dislike Moderately	Neither Like nor Dislike	Like Moderately	Like Very Much
1	2	3	4	5

TABLE 7

Mean Fit Ratings for Pants

	Pant A	**Pant B**
	$\bar{x}$	$\bar{x}$
Overall Fit	3.41	4.17
Waist	3.42	4.13
Seat Area	3.32	4.10
Length	3.55	4.03

All ratings for both pairs of pants were positive, indicating that the fit of both was *liked.* The mean fit rating for Pant B was significantly higher in all areas (F(1,143)>=41.02 p<0.0025 in all cases). The difference between the mean ratings scores is quite large for each area, suggesting that the fit of Pant B was favored over A.

The description of fit mean rating was consistent for both pairs of pants. Both had an average rating of approximately 3.3 for all areas questioned. The data suggest that, on average, the pants were rated as being *neither too tight nor too loose*.

The mean ratings of leg length did not vary between pants and, in general, were reported as *just right*. However, when gender was taken into account, the female mean score was significantly higher ($F(1,141)=18.44$, $p<0.0025$) than was the males' ($\bar{x}=3.07$, 3.45 for males and females respectively). This suggests that a number of female subjects found the length of the pant legs *slightly too long*. The *overall length* mean ratings clustered around *just right* (3.0) and were consistent for both pants, data collection points, and gender.

Design and Utility of Pants

Table 8 lists the mean ratings for both pants for all *design and utility* questions.

TABLE 8

Design and Utility Ratings

		Pant A	**Pant B**
		$\bar{x}$	$\bar{x}$
Overall Look	(1=Really Dislike, 5=Really Like)	3.13	3.98
Design of Pant Leg	(1=Really Dislike, 5=Really Like)	3.34	3.85
Ease of Stenciling	(1=Very Difficult, 5=Very Easy)	3.96	3.55
Suitability to Job	(1=Very Unsuited, 5=Very Suited)	3.15	3.52
Ease of Pocket Use	(1=Very Difficult, 5=Very Easy)	3.75	3.91

The mean *overall look* ratings differed significantly by garment ($F(1,139)= 46.45$, $p<0.0025$). Pant A, on average, was rated close to *fair* ($\bar{x} = 3.13$), while Pant B was rated close to *like* ($\bar{x}= 3.98$). Both means were, however, positive.

Both pants received positive ratings for the *design of the pant leg*. However, Pant B received significantly higher ratings ($\bar{x}=3.85$) than did A (3.34), $F(1,143)=14.57$, $p<0.0025$.

In addition, both pants were rating positively for *ease of stenciling*. However, Pant A received a significantly higher ($F(1,138)=27.61$, $p<0.0025$) mean rating ($\bar{x} = 3.96$) than did Pant B ($\bar{x} = 3.55$).

Both pants received positive mean ratings for suitability to job ($\bar{x} = 3.15$, 3.52 A & B,

respectively), with mean ratings close to *somewhat suited.* The ratings were, however, statistically different ($F(1,139)=12.57$, $p<0.0025$), with Pant B being rated as being more suited to subjects' jobs.

The pockets were found to be *fair* to *somewhat easy* to use, with the mean ratings for both pants above 3.5. There were no significant differences between pants.

Durability

Table 9 shows the mean ratings for *durability* and *maintenance of appearance*.

TABLE 9

Durability and Ease of Care Ratings

		Pant A	Pant B
		$\bar{x}$	$\bar{x}$
Durability	(1=Not Durable, 5=Very Durable)	3.69	4.03
Maintenance of Appearance	(1=Very Poorly, 5=Very Well)	3.68	3.61

Both pants received positive mean ratings for *durability* and *maintenance of appearance*, and there were no significant differences between the ratings.

Comfort

Table 10 displays the mean ratings for *comfort* (in hot and cold conditions, and overall) for both pair of pants.

Scale:

Very Uncomfortable	Uncomfortable	Acceptable	Comfortable	Very Comfortable
1	2	3	4	5

TABLE 10

Comfort ratings in Hot and Cold Conditions and Overall

	Pant A	**Pant B**
	$\bar{x}$	$\bar{x}$
Overall	3.47	3.98
When Hot	3.38	3.42
When Cold	3.32	3.96

Ratings for *Overall* comfort and *comfort in hot and cold conditions* were positive for both pants. In *hot conditions*, both pants received similar mean ratings, which did not differ significantly. However, Pant B received significantly higher ratings in *cold conditions* and *overall* ($F(1,137)=40.84$, $p<0.0025$; $F(1,140)=21.31$, $p<0.0025$, *cold conditions* and *overall*, respectively). These data suggest that Pant B was found to be more comfortable than was Pant A in most situations.

Overall Rating

The following scale was used to rate the *overall rating* for the pants:

Scale:

Very Poor	Poor	Fair	Good	Very Good
1	2	3	4	5

The mean overall ratings for the pants were positive, falling between *fair* and *good* ($\bar{x}$=3.42, 3.94 Pants A and B, respectively). These mean ratings differed significantly ($F(1,140)=14.58$, $P<0.0025$), suggesting that overall Pant B was favored more than Pant A.

Discussion and Conclusions

Shirts

For each of the five main factors of: fit, design and utility, durability, comfort, and overall acceptance, both shirts received positive and favorable ratings. This suggests that either shirt

would be an adequate replacement for the current chambray shirt. However, it is clear from the data that Shirt B was preferred over Shirt A. In four out of the five factors examined (*fit preference*, *overall look of the design*, *comfort in both hot and cold environments*, *overall rating*), Shirt B received significantly higher ratings than Shirt A.

Pants

Similarly, both pairs of pants received positive and favorable ratings on all five of the factors examined. This suggests that both pants would be adequate replacements for the current dungaree pants. However, Pant B was rated higher more often than was Pant A. Pant B had significantly higher ratings in all areas of *fit preference, overall look of the design, design of the pant leg, comfort for in both cold environments and overall comfort*, and the final *overall rating.* As with the shirts, Pant B received significantly higher ratings than Pant A, in four out of the five categories. The only exception to this trend, was that Pant A received a higher rating for *ease of stenciling or attaching name tags.* This however, would appear less important to factors such as comfort, and fit preferences. Therefore, Pant B appears to be the higher rated pant.

Phase 2 - Modified Commercial Uniforms

Methodology

Design

A within-subject design was used to allow each subject to wear each uniform. By allowing each test participant to wear every uniform type, situational factors such as weather, job classification and geographic location were controlled.

Subjects

All three uniforms were originally issued to 1278 male and female subjects. Subjects were located on 15 ships and shore commands across the East and West Coast. The mean age of the subjects was 28.

Procedures

The test period was six months. The three test uniforms were worn in place of subjects' current dungaree uniform. The test uniforms were worn in rotation and were laundered as necessary. When one uniform was being laundered, another uniform was worn in its place. For example, if a subject began the test wearing *Uniform B*, he/she might have switched to *Uniform C* when *Uniform B* needed to be laundered. This procedure was repeated throughout the six month test.

Uniforms were initially issued based upon self-reported sizes. A shirt or pant was not issued until both the fitter and subject felt that the garments were the proper size. Subjects were also encouraged to tailor their pants, to optimize their fit. An issue sheet was completed for each subject, detailing their self-reported size, the sizes of the garments issued and demographic information. A sample of the issue sheet can be found in Appendix C. It should be noted that for the women's version of Pant C, the number of garments procured in each size was not sufficient to fit all female subjects properly. Consequently, in some instances an ideal fit could not be obtained.

The sailors were visited at the midpoint (3 months) and endpoint (6 months) of the wear test to complete a *Wear Test Questionnaire*. The questionnaire was the same for the mid- and endpoints. The mid- and endpoint data collections were used to determine how well the garments stood up over time, and to see if user preferences changed with continual use of the garments. The user questionnaires were designed to obtain information on: fit, design, utility, durability and comfort. Appendix D contains a sample survey.

Questionnaires

Fit and Preference questionnaires were used to elicit test participants' opinions about the shirts and pants under study. The questionnaires were divided into five sections, each addressing the following factors: *fit*, *design and utility*, *durability*, *comfort* and *overall acceptance*.

The *Fit* section was constructed to identify those test participants who thought they were wearing the correct size garments and to characterize the fit of the garments. Self-report measures were used to determine proper fit and were used at the issue, mid- and endpoints. While self-report is not always the most accurate method of reporting, the *perception* of properly fitting garments was a critical starting point of the evaluation. If test participants did not feel the uniforms fit properly, then their opinions about other characteristics of the garments would likely be negatively influenced.

Fit was characterized by asking test participants to rate it along several dimensions. For example, *length* was rated as *too long*, *just right* or *too short*; *fit* was rated as being *close-fitting regular fit* or *baggy*.

The *Design* and *Utility* sections measured the degree to which the design of the garments were acceptable to the wearers. Factors such as *suitability*, *ability to perform operational activities*, *ability to use pockets* and *ability to label garments* were rated for each garment under study.

The *Durability* section measured all durability problems that test participants encountered while wearing the garments. Respondents were asked to specify the types of problems and to identify all areas of each garment where durability problems occurred.

The *Comfort* section measured test participants' ratings of overall comfort and comfort in hot and cold environmental conditions for each garment under study.

Results

Demographics of Respondents

Table 11 shows the number of surveys returned for each phase of the test. Five hundred and one subjects completed all three phases of the study. The difference in the number of respondents at each data collection point was the result of attrition of test participants (due to reassignment, illness, etc.), and of a difference of response rate at each data collection point (i.e., some subjects provided responses at only one of the data collections).

Researchers involved in similar survey work - where test items are initially issued and the experimenters return at a later date to conduct surveys - assume that they will encounter an attrition rate of approximately 50%. In this study (as in Phase I), because there were two data collections (and therefore, an additional chance for attrition) and the subjects who were used for

the final analysis had to have completed surveys at **both** the mid and end points, it was expected that this number would be lower than 50%.

In deed, the final group of subjects selected for analysis was approximately 39% of the original group. This is an acceptable attrition rate given the two data collections, and that the analysis included only those subjects who were present for both data collections.

TABLE 11

Returned Surveys

Survey Point	N
Issue	1278
Mid	839
End	714
All Phases	501

Demographic Information

As can be seen in Table 12 below, nearly 30% of all respondents were female. Over 33% of respondents were female from the East coast , while slightly more than 26% of the respondents were female from the West coast.

TABLE 12

Surveys by Gender

	Male		Female	
	n	%	n	%
East Coast	164	66.7	82	33.3
West Coast	188	73.7	67	26.3
Overall	352	70.1	149	29.9

Responses By Ship and Shore Commands

The number of responses by location is presented in Table 13. Forty-nine percent of responses came from the East Coast and 50.9% from the West.

TABLE 13

Number of Responses by Ship

Ship	n	%
Arctic	49	9.8
Boxer	50	10.0
Briscoe	38	7.6
Comstock	46	9.2
Constellation	26	5.2
CVW2	0	0.0
Emory Land	41	8.2
George Washington	0	0.0
Jacksonville	21	4.2
LaJolla	17	3.4
McKee	31	6.2
NAS-Norfolk	25	5.0
NAS-SD	24	4.8
SIMA-VA	36	7.2
SIMA-SD	62	12.4
VCR40	15	3.0
Wasp	20	4.0

Age

The mean age of respondents was 27.65 (sd=5.85). The age of respondents were subjected to a two factor ANOVA, with gender and coast serving as between-subject factors. There were no significant differences found in the mean ages of respondents, regardless of gender or coast.

Ethnicity

Table 14 presents the ethnic background of test participants by coast. Two Kruskal-Wallis one-way analysis of variance were applied to the ethnographic data, with gender and coast serving as between-subject factors. Ethnic distribution was not significantly different between gender, but was significantly different between the East and West coasts ($\chi^2 = 5.24$, df=1, $p<0.05$). Compared to the East coast, the West coast had a higher representation of Asian Pacific Islanders (n=5 and 37, respectively), and a slightly lower representation of both Afro-Americans (n=126) and Caucasians (n=261).

TABLE 14

Number of Responses by Ethnicity

	East		West		Overall	
	n	%	n	%	n	%
American Indian	5	2.1	1	0.4	6	1.2
Asian / Pacific Islander	5	2.1	37	15.0	42	8.6
Afro-American	69	28.5	57	23.1	126	25.8
Hispanic	17	7.0	18	7.3	35	7.2
Mixed	7	2.9	12	4.9	19	3.9
Caucasian	139	57.4	122	49.4	261	53.4

Analysis of Shirt and Pants Data

As in Phase I, the analyses of the shirt and pants data were conducted separately, with each being subjected to approximately 20 different analyses. Due to the large numbers of comparisons being made, the *Bonferoni correction* was applied to all analyses. The Bonferoni correction reduces the chances of obtaining false positive results (i.e., saying there is a difference in the data, when there is actually no difference).

Adjusted Significance Level = Alpha Level / Number of Analyses
= 0.05 / 20
= 0.0025

Shirts

Fitting/Non-Fitting Subjects

Respondents were divided into two groups: those who reported that both shirt types fit (classified as *Fitting*), and those who reported that both shirts did not fit (*Non-Fitting*). The combined *fitting/non-fitting* data for both shirts were subjected to two Mann-Whitney U tests, with coast and gender serving as between-subjects factors. There were no significant differences in the number of test participants for whom Shirts A/B or C fit, regardless of gender or coast. *Table 15* presents the overall number of subjects classified as *fitting* or *non-fitting*.

TABLE 15

Number of Respondents Classified as "Fitting"

	n	%
Fitting	352	70.3
Non-Fitting	149	29.7

The *fitting/non-fitting* data for Shirt A/B and Shirt C, were subjected to a Wilcoxen Matched-Pairs Signed-Ranks test. Shirt C fit significantly more test participants than did Shirt A/B (83.8%, 76.6%, respectively) (Z=-3.13, p<0.01). *Table 16* displays the fit data for both shirts.

TABLE 16

Fit by Shirt

	Shirt A/B		**Shirt C**	
	n	%	n	%
Fitting	384	76.6	420	83.8
Non-Fitting	117	23.4	81	16.2

Table 17 presents data from *non-fitting* subjects, listing the reasons the shirts did not fit. At the midpoint data collection, the most common reason given for *both* shirts not fitting was that they were *too tight* (Shirt A/B = 69%, Shirt C = 79%). At the endpoint, this was still the most common reason given for Shirt A; however, equal numbers of respondents said Shirt C was either too tight (38%) or too loose (38%).

TABLE 17

Reasons Given for Non Fitting Subjects

	Midpoint				**Endpoint**			
	Shirt A/B		**Shirt C**		**Shirt A/B**		**Shirt C**	
	n	%	n	%	n	%	n	%
Too Tight	43	69.4	27	79.4	47	59.5	13	38.2
Too Loose	9	14.5	4	11.8	13	16.5	13	38.2
Other Reasons	10	16.1	3	8.8	19	24.1	8	23.5

Note: Ns do not sum to 149 because some subjects did not fit into all shirts.

Fit of Shirts

Only subjects who responded that their shirts fit (n= 352) were retained for the following analyses. All fit questions were subjected to split-plot ANOVAs, with garment type (Shirt A/B, Shirt C) and Data Collection Point (Midpoint, Endpoint) serving as within-subject variables, and gender and coast serving as between-subject variables.

No significant differences were found in the overall mean ratings of *shirt sleeve length* or *overall length* (Overall mean ratings for both shirts; Overall Length $\bar{x}$ =2.03, Sleeve Length $\bar{x}$ = 1.98) correspond to "Just Right" on the scale.

Fit Description

The mean overall fit description ratings for both garments suggest test participants consider each area to be a *baggy fit*. The *description of fit* for the shoulders, chest, arms, neck, and stomach, follow the same pattern of response as the overall ratings.

Acceptability of Fit

Table 18 lists the mean fit ratings for each shirt for each body area broken down by gender and coast.

Overall: Shirt C received an average rating of 4.09, while Shirt A/B received a mean rating of 3.85. This difference was significantly different (F=29.37 (1,341) p<0.01).

Shoulders: Mean ratings for the fit of the shoulders differed significantly (F=25.73 (1,339) p<0.001), with Shirt C receiving a higher average rating ($\bar{x}$ = 3.88, 4.08, A/B and C, respectively).

Chest: Mean ratings for the fit of the chest differed significantly (F=25.31 (1,339) p<0.001), with Shirt C receiving the higher rating ($\bar{x}$ = 3.89, 4.10, A/B and C, respectively).

Arms: Mean ratings for the fit of the arms differed significantly (F=27.86 (1,340) p<0.001), with Shirt C receiving a higher rating ($\bar{x}$ = 3.80, 4.02, A/B and C, respectively).

Neck: Mean ratings for the fit of the neck differed significantly (F=30.32 (1,340) p<0.001), with Shirt C receiving the higher rating ($\bar{x}$ = 3.88, 4.09, A/B and C, respectively).

Stomach: Mean ratings for the fit of the stomach differed significantly (F=30.95 (1,339) p<0.001), with Shirt C receiving the higher rating ($\bar{x}$ = 3.85, 4.11 A/B and C, respectively).

Scale:

Dislike Very Much	Dislike Moderately	Neither Like nor Dislike	Like Moderately	Like Very Much
1	**2**	**3**	**4**	**5**

TABLE 18

Mean Fit Ratings for Shirts

	Midpoint				**Endpoint**			
	Shirt A/B		**Shirt C**		**Shirt A/B**		**Shirt C**	
Gender	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$
Overall Fit	3.98	3.79	4.10	4.28	3.82	3.68	4.02	4.08
Shoulders	4.02	3.79	4.10	4.24	3.84	3.70	3.99	4.12
Chest	4.04	3.82	4.13	4.28	3.86	3.66	4.00	4.09
Arms	3.91	3.76	4.03	4.19	3.77	3.59	3.95	4.00
Neck	4.01	3.85	4.08	4.25	3.82	3.72	4.03	4.15
Stomach	3.97	3.75	4.10	4.20	3.84	3.68	4.01	4.13

Design of Shirts

Unless otherwise stated, all design questions were subjected to split-plot ANOVAs, with garment type (Shirt A/B, Shirt C) and Data Collection Point (Midpoint, Endpoint) serving as within-subject variables, and gender and coast serving as between-subject variables.

Overall Look: The overall mean ratings differed significantly by data collection point ($F = 21.53$ $(1,342)$ $p<0.001$). The endpoint ratings were lower than the midpoint ($\bar{x} = 4.32, 4.09$, midpoint and endpoint, respectively). The mean ratings for the shirts did not differ significantly ($\bar{x} = 4.18, 4.23$ Shirt A/B and C, respectively).

Restriction in Activities: Table 19 displays subject responses to whether they could perform all their daily activities. Two Wilcoxen Matched-Pairs Signed Rank tests were applied to both the midpoint and endpoint data collections. Over 93% of subjects stated they had no restrictions to their activities as a result of wearing the shirts. The distribution of "Yes" and "No" responses did not change significantly for shirts between data collection points.

Suitability to Job: Table 19 displays subject responses to whether the shirts were suitable to their particular jobs (i.e., designed acceptably to perform duties). Over 87% of the subjects responded

that the shirts were *suited* to their work. Two Wilcoxen Matched-Pairs Signed Rank tests were applied to both the midpoint and endpoint data collections. The distribution of "Yes" and "No" responses was not significantly different between the shirts.

TABLE 19

Design of Uniforms: Restriction in Activities, and Suitability

	Shirt A/B				Shirt C			
	Mid		End		Mid		End	
	Yes	No	Yes	No	Yes	No	Yes	No
Restriction (%)	96.0	4.0	93.9	6.1	94.3	5.7	94.3	5.7
Suitability (%)	89.9	10.1	89.9	10.1	88.3	11.7	87.4	12.6.

Pockets: Mean ratings for the ease of use of the front pockets ($\bar{x}$ = 4.18, 4.23, for Shirts A/B and C, respectively) were not significantly different. The mean ratings correspond to the pockets being *Fairly Easy* to use.

Durability

Frequency of Wear: The average total wear time (days) for each shirt varied significantly by garment (F= 10.72 (1,270) p<0.002). Shirt A/B was worn an average of 8 days longer ($\bar{x}$ = 52.52 days, 46.30 days) than was Shirt C. Wear time also differed significantly by gender: males wore the shirts an average of 9 days longer than did the females ($\bar{x}$ = Males 51.87 days, Females 42.38 days).

Durability: The mean durability rating varied by garment type (F=37.38 (1,328) p<0.001). Ratings for Shirt C were higher than those for Shirt A/B ($\bar{x}$ = 2.91, 3.15 Shirts A and C, respectively). Both mean ratings correspond to *Durable* on the verbal rating scale.

Ease of Care: Mean ratings for the *ease of care after laundering* differed significantly by garment (F = 418.55 (1,336) p<0.001), Shirt C's mean rating was much greater than that of Shirt A/B ($\bar{x}$ = 2.28, 3.91, Shirts A/B and C, respectively). The mean rating for Shirt A/B suggests that it maintained its appearance *Poorly;* in comparison, the average rating for Shirt C suggests that it maintained its appearance *Well.*

Laundering Frequency: The mean frequency with which Shirts A and C ($\bar{x}$ = 4.13, 4.20, respectively) were laundered were not significantly different.

Comfort

Table 20 presents the mean ratings of three levels of comfort: overall, in hot conditions and in cold conditions.

Scale:

Very Uncomfortable	Uncomfortable	Acceptable	Comfortable	Very Comfortable
1	**2**	**3**	**4**	**5**

TABLE 20

Mean Comfort Ratings

	Shirt A/B		**Shirt C**	
	Mid	**End**	**Mid**	**End**
Conditions	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$
Hot	2.90	2.55	3.38	3.18
Cold	3.85	3.65	3.69	3.63
Overall	3.48	3.22	3.63	3.52

Hot Conditions: The average rating for comfort in hot conditions for Shirt C ($\bar{x}$= 3.28) was significantly higher than that received by Shirt A/B ($\bar{x}$= 2.73), $F = 78.44$ (1,329) $p<0.001$. Overall, ratings were higher at the midpoint than at the endpoint, $F = 24.42$ (1,329) $p<0.001$ ($\bar{x}$ = 3.14, 2.87 mid- and endpoint, respectively).

Cold Conditions: Mean ratings for comfort in cold conditions did not differ significantly.

Overall: Mean ratings for comfort differed significantly by shirt type ($F = 23.89$ (1,328) $p<0.001$). Shirt A's mean rating was slightly lower than that of Shirt C ($\bar{x}$ = 3.34, 3.58, respectively). Mean comfort ratings also differed by data collection point ($F = 15.30$ (1,328) $p<0.001$): ratings at the midpoint were higher than those for the endpoint ($\bar{x}$ = 3.56, 3.37 mid- and endpoint, respectively). All ratings were in the positive end of the scale and fell between *Acceptable* and *Comfortable*.

Overall

The mean overall ratings for each shirt are presented in Table 21.

Scale:

Very Poor	Poor	Fair	Good	Very Good
1	2	3	4	5

TABLE 21

Overall Shirt Ratings

	Shirt A/B		Shirt C	
	Male	Female	Male	Female
	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$
Overall	3.29	2.80	3.87	4.01

The mean overall ratings for each shirt were significantly different ($F= 136.47$ $(1,340)$ $p<0.001$). The mean rating for Shirt A/B was lower than the mean rating for Shirt C ($\bar{x} = 3.16$, 3.91, respectively). Shirt A, was on average, rated as being *Fair*, while Shirt C was rated as being *Good.* In addition, men rated Shirt A/B more favorably than did females, but females rated Shirt C *more* favorably than did males ($F = 16.71$ $(1,340)$ $p<0.001$).

Comparison

Subjects were asked to rank each of the garments along four factors: fit, comfort, durability, and appearance. Table 22 presents the frequencies of these ranks for each garment, broken out by gender and data collection point.

TABLE 22

Frequencies of Shirt Number 1 Rankings

%	Shirt A/B			Shirt C		
Midpoint	M	F	All	M	F	All
Fit	68.9	51.1	63.9	66.5	78.5	69.9
Comfort	69.2	52.1	64.4	62.4	77.4	66.7
Durability	60.9	45.2	56.4	72.6	77.7	74.0
Appearance	45.4	19.4	38.1	70.6	83.0	74.1
Endpoint						
Fit	66.9	46.7	61.4	64.4	81.3	68.9
Comfort	63.0	48.4	58.9	66.1	79.1	69.6
Durability	58.9	37.0	53.0	70.6	80.2	73.2
Appearance	40.8	25.8	36.7	71.5	84.9	75.1

The rank data were subjected to Wilcoxen Matched-Pairs Signed-Ranks test for each category. For the midpoint data, the rank distributions for each shirt were significantly different for durability and appearance ($Z = -3.65, -6.43$, respectively $p<0.001$). In both cases, Shirt C received significantly more top ranks than did Shirt A, especially for the appearance category. The endpoint rank distributions also differed significantly for durability and appearance ($Z = -3.92, -6.87$, respectively $p<0.001$), with shirt C receiving more top ratings.

Comparison to Current Chambray Shirt

Table 23 displays the mean ratings of comparison for subjects' favorite shirt (i.e., top-ranked shirt) to the current chambray shirt. The mean ratings did not vary between gender, coast or data collection for any of the four areas. All mean ratings fell between *Like Current the Same* as the study uniforms and *Like Current More* than the study uniforms.

Scale:

Like **Current** Much Less	Like **Current** Less	Like **Current** Same	Like **Current** More	Like **Current** Much More
1	**2**	**3**	**4**	**5**

TABLE 23

Mean Comparison Ratings

	Mid	**End**
	$\bar{x}$	$\bar{x}$
Fit of Pants	3.15	3.10
Comfort	3.15	3.13
Durability	3.20	3.03
Appearance	3.20	3.10

Table 24 lists the frequencies for the comparison data for the endpoint data collection.

TABLE 24

Overall Comparison Ratings

Rank	**1**	**2**	**3**	**4**	**5**
Fit of shirts	14.2	14.2	37.9	14.8	18.8
Comfort	14.2	15.4	33.9	16.8	19.7
Durability	16.5	18.2	30.5	15.1	19.7
Appearance	17.9	16.2	26.8	15.1	23.4

In all cases the number of subjects liking the old shirt better is greater than the number of subjects liking the new.

Pants

Fitting/Non-Fitting Subjects

Respondents were divided into two groups: those who reported that all three pant types fit (classified as *fitting*), and those who reported that any of the three pants did <u>not</u> fit (*non-fitting*). Table 25 displays the number of subjects classified in the *fitting* group.

TABLE 25

Number of Respondents Classified as "Fitting"

	n	%
Fitting	297	59.3
Non-Fitting	204	40.7

The *fitting/non-fitting* data for Pants A, B, and C were subjected to a Friedman ANOVA. The distribution of *fitting* and *non-fitting* subjects for each pair of pants was not significantly different.

The overall *fitting/non-fitting* data were subjected to two Mann-Whitney U tests, with coast and gender serving as between-subject factors. The number of *fitting* subjects to *non-fitting* subjects did not differ significantly between coasts; however a significant difference was found between males and females ($Z=-6.42$, $p<0.01$). Table 26 lists the fit responses for males and females. Over 68% of male subjects responded that all three pants fit, whereas only slightly more than 37% of the female subjects indicated that all three pants fit.

TABLE 26

Pant "Fit" / "No-Fit" by Gender

	Male		**Female**	
	n	%	n	%
Fitting	241	68.5	56	37.6
Non-Fitting	111	31.5	93	62.4

Table 27 displays the percentages of males and females who fit into each of the three pant types. For all three pairs of pants, female subjects had a lower percentage of "fit" responses. This was especially true of Pant C, with almost 50% of female subjects stating the pants did not fit.

Fit data for each pair of pants were subjected to a Mann-Whitney U Test, with gender serving as a between-subjects factor. The distribution of *fit/ non-fit* responses between male and female subjects were significantly different for each pant ($Z=-3.07, p<0.01$; $Z=-2.26, p<0.05$; $Z=-6.09, p<0.01$; for Pants A, B, and C, respectively).

TABLE 27

"Fit" / "No-Fit" by Pant by Gender

	Pant A				Pant B				Pant C			
	Male		Female		Male		Female		Male		Female	
	n	%	n	%	n	%	n	%	n	%	n	%
Fitting	293	83.2	106	71.1	289	82.1	109	73.2	281	79.8	79	53.0
Non-Fitting	59	16.8	43	28.9	63	17.9	40	26.8	71	20.2	70	47.0

Tables 28 and 29 list the reasons provided by the subjects for the pants not fitting. For Pants A and B, nearly 60% of all *non-fitters* indicated the pants were *too tight.* The same reason was given by the males for Pant C; however, 59.2% of the females reported that the pants did not fit because they are *too loose*. This pattern occurred at both the mid- and endpoints, and is likely due to the insufficient number of pants available in each size (as discussed earlier).

TABLE 28

Reasons for "Non-Fitting" Responses - Midpoint

	Pant A				Pant B				Pant C			
	Male		Female		Male		Female		Male		Female	
	n	%	n	%	n	%	n	%	n	%	n	%
Too Tight	25	61.0	16	64.0	20	64.5	11	57.9	22	55.0	11	22.4
Too Loose	12	29.3	5	20.0	9	29.0	4	21.1	11	27.5	29	59.2
Other Reasons	4	9.8	4	16.0	2	6.5	4	21.1	7	17.5	9	18.4

TABLE 29

Reasons for "Non-Fitting" Responses - Endpoint

	Pant A				Pant B				Pant C			
	Male		Female		Male		Female		Male		Female	
	n	%	n	%	n	%	n	%	n	%	n	%
Too Tight	20	62.5	16	61.5	21	67.7	16	66.7	13	46.4	11	21.6
Too Loose	9	28.1	5	19.2	7	22.6	4	16.7	11	39.3	30	58.8
Other Reasons	3	9.4	5	19.2	3	9.7	4	16.7	4	14.3	10	19.6

The *fit /non-fit* data were subjected to four two-factor split-plot ANOVAs, with size (*self-reported size, issued size*) serving as within-subject factors, and fit (*fitting*, *non-fitting*) serving as between-subject factors. Table 30 presents self-reported sizes and issued sizes for each pant.

For all pants, there was no difference between self-reported and actual sizes issued for either the *fitting* and *non-fitting* test participants.

For Pants A and B, the size differed significantly between self-reported size and issued pant size. For males, the issued waist size was approximately 0.2" greater than that which was reported. For females, the issued size was approximately one (1) size greater than the reported size. For Pant C, male self-reported sizes did not differ significantly from those issued; whereas, the female self-reported size did differ significantly from the issued size (F=63.47 (1,132), $p<0.001$) where the issued size was two sizes smaller than the self-reported size ($\bar{x}$=14.8, 13.1; self-reported and issue, respectively).

TABLE 30

Self Reported Sizes and Issued Sizes

	Self		Pant A		Pant B		Pant C	
	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd
Male Size	33.8	3.0	33.9	3.1	34.0	3.1	34.0	3.3
Female Size	14.8	2.9	15.8	3.1	15.6	3.2	13.1	2.8

In order to understand the differences in fit among female test participants more fully, ethnicity was included in the analysis. Female ethnographic data were subjected to a Mann-Whitney U test with fit of Pant C serving as a between-subjects factor. There were no differences in race distribution between *fitting* subjects and *non-fitting* subjects.

A tally of comments for the fit of Pant C was produced for *non-fitting* female subjects. Twenty-four subjects provided comments; they are displayed in Table 31.

TABLE 31

Female Comments for "Non-Fitting" of Pant C

n=24	n
Crotch too Loose/Long	8
Waist Tight / Hips Loose	4
Size too Large	4
Ill Fitting	2
Baggy	1
Waist Tight	1
Seat	1
Hip and Seat Large	1
Hips too Baggy	1
Too Short	1

<u>*Fit of Pants*</u>

Only the subjects who reported that the three pants fit (n=297) were retained for the following analyses. Fit was assessed along three factors: length of pants, fit at specific body areas and preference rating of fit at specific body areas. All fit questions were subjected to split-plot ANOVA, with garment type (Pant A, Pant B, Pant C) and Data Collection Point (Midpoint, Endpoint) serving as within-subject variables, and gender and coast serving as between-subject variables.

Length

Overall Length: All ratings of pant length were positive, as evidenced by an overall mean rating of 2.0. However, the overall pant length ratings varied significantly between gender (F=56.09 (1,277) p<0.001) and data collection point (F=12.53 (1,277) p<0.001). There was an increased number of West Coast female subjects who rated the pants as *Too Long* at the Midpoint collection compared to the endpoint data collection.

Crotch Length: There was no overall difference in mean crotch length ratings among the three pant types. However, there was a significant difference found between male and female ratings. The mean crotch length rating for females was slightly higher than for males ($\bar{x}$=2.20, 2.00, respectively). Both ratings, however, correspond to *Just Right*, with the female mean rating suggesting that slightly more females rated the pants as *Too Long* than males.

Fit Description

Table 32 presents the means for all description of fit questions broken down by gender.

Overall Fit: Mean overall fit description ratings differed significantly by garment type (F=27.39 (2,558) p<0.001). The mean rating for Pant C ($\bar{x}$ = 2.07) was greater than either Pant A or B ($\bar{x}$ = 2.01, 2.00, respectively). This difference, while *statistically significant*, was so small that it has little practical meaning. In addition, females tended to rate Pant C as being *baggy* more often than did males F=13.59 (2,558) p<0.001. ($\bar{x}$ = 2.22).

Waist: No significant differences were found among the mean description ratings of fit for the waist area for the three pant types.

Seat Area: A significant difference was found in the mean ratings for the seat area for the three pants (F=17.55 (2,558) p<0.001). Pant C's mean rating was higher ($\bar{x}$ = 2.06) than those for Pants A or B ($\bar{x}$ = 1.98 and 1.99, respectively).The high mean female rating for Pant C ($\bar{x}$ = 2.22), indicates more female subjects found the seat area to be a *baggy fit*, rather than *regular* fit (F=13.59 (2,558) p<0.001).

Thigh: The mean ratings for the thigh area differed significantly by garment (F=21.21 (df=2,554) p<0.001). Pant C's rating was higher ($\bar{x}$ = 2.04) than those for Pants A or B ($\bar{x}$ = 1.97 and 1.98, respectively). In addition, the females tended to rate Pant C as being *baggy* more often than did the males F=12.48 (2,554) p<0.001 ($\bar{x}$ = 2.15).

Scale:	Close Fit	Regular Fit	Baggy Fit
	1	2	3

TABLE 32

Mean Description of Fit Ratings

	Pant A		Pant B		Pant C	
	Male	Female	Male	Female	Male	Female
	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$
Overall Fit	2.00	2.02	2.00	2.00	2.04	2.22
Waist	1.98	2.06	2.00	2.05	1.99	2.02
Seat Area	1.98	2.01	1.98	2.01	2.02	2.21
Thigh	1.98	1.93	1.98	1.93	2.02	2.15

Rating of Fit

Overall Fit: Mean ratings of overall fit differed significantly by data collection ($F = 13.04$ $(1,287)$ $p<0.001$), with the midpoint having higher ratings than the endpoint ($\bar{x} = 4.24, 4.09$, respectively).

Waist: No differences were found in the mean overall ratings for *fit of the waist* among the three types of pants. However, ratings differed significantly by data collection ($F = 21.75$ $(1,285)$ $p<0.001$). Test participants rated all three pants lower at the endpoint than they did at the midpoint ($\bar{x} = 4.04, 4.20$, respectively). In general, females rated the fit of the waist lower than did men. In addition, females rated the fit of the waist lower at the endpoint ($\bar{x} = 3.67$) than at the midpoint ($\bar{x} = 4.19$), $F = 12.56$ $(1,285)$ $p<0.001$.

Seat Area: No differences were found in mean overall ratings of the *seat area* among the three types of pants. However, ratings differed significantly by data collection ($F = 11.36$ $(1,285)$ $p<0.001$): the endpoint had a lower rating than the midpoint collection ($\bar{x} = 4.07, 4.22$, respectively).

Thigh: No differences were found in the mean overall ratings for the *thigh* among the three types of pants. However, the garment by gender interaction was significant ($F = 6.93$ $(2,570)$ $P<0.002$), where the male preference score was lower for Pant C than for Pants A and B, whereas the female mean score is higher for Pant C than for Pants A and B (Male $\bar{x} = 4.24, 4.29, 4.04$ for Pants A, B, and C respectively; Female $\bar{x} = 3.92, 3.90, 4.09$).

<u>Design of Pants</u>

Unless otherwise stated, all design questions were subjected to split-plot ANOVAs, with garment type (Pant A, Pant B, Pant C) and Data Collection Point (midpoint, endpoint) serving as within-subject variables, and gender and coast serving as between-subject variables.

Overall Look: There were no significant differences among the mean overall ratings for the *overall look* of the pants. However, the males rated Pants A and B ($\bar{x} = 4.20, 4.30$, respectively) significantly higher than they did Pant C ($\bar{x} = 3.91$). In comparison, females rated Pant C ($\bar{x} = 4.15$) higher than they did Pants A or B ($\bar{x} = 3.95, 3.96$, respectively). This suggests that males and females had opposite opinions about the overall look of the pants: females preferred Pant C over Pants A and B, while the males preferred the look of Pants A and B over C. These differences, although statistically significant, were slight and fell into the range of *Like moderately.*

Design of the Pant Legs: There was no difference among the mean ratings for the look of the pant legs for all three pant types ($\bar{x} = 4.25, 4.30, 4.17$ for Pants A, B, and C, respectively).

Ability to Stencil Name Tags: Table 33 displays subject responses to whether they could easily stencil or attach their name tag to each pair of pants. Two Friedman two-way ANOVAs were applied to the mid- and endpoint data. There was no difference found among the three types of pants in subjects' ability to attach their names to the pants. This was true for both data collection points.

Restriction in Activities: Subjects were asked to indicate whether or not the pants restricted their ability to perform their mission-related activities. These data are reported below in Table 33. Over 94% of subjects stated they could perform all their daily activities. Those who reported they could not, sited fit problems as the reason for the impediment. Two Friedman two-way ANOVAs were applied to both the mid- and endpoint data. The distribution of *Yes* and *No* responses did not change significantly for any pant type.

Suitability to Job: Table 33 displays subject responses to whether the pants were suitable to their particular job. Over 91% of the subjects responded that the pants are "suited" to their work. Two Friedman two-way ANOVAs were applied to both the mid- and endpoint data. The distribution of *Yes* and *No* responses did not change significantly between pant or data collection.

TABLE 33

Design of Uniforms: Ability to Stencil, Restriction in Activities, and Suitability

	Pant A				**Pant B**				**Pant C**			
	Mid		**End**		**Mid**		**End**		**Mid**		**End**	
	Yes	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
Stencil (%)	83.3	16.7	81.3	18.7	81.9	18.1	79.2	20.8	95.1	4.9	95.2	4.8
Restriction (%)	95.9	4.1	96.9	3.1	96.2	3.8	97.3	2.7	94.8	6.2	96.9	3.1
Suitability (%)	95.5	4.5	95.9	4.1	96.9	3.1	96.6	3.4	92.2	7.8	91.5	8.5

Front Pockets: Mean ratings for the ease of use of the font pockets ($\bar{x}$ = 4.30, 4.34, 4.33 for Pant A, B, and C, respectively) were not significantly different. The numerical mean ratings correspond to the verbal label *Fairly Easy* to use.

Rear Pockets: Mean ratings for the ease of use of the rear pockets ($\bar{x}$ = 4.33, 4.33, 4.32 for Pant A, B, and C respectively) were not significantly different. The numerical mean ratings correspond to the verbal label *Fairly Easy* to use.

Durability

Frequency of Wear: The total wear time (days) for each pant did not vary significantly among the pant types ($\bar{x}$ = 52.1, 52.80, 46.55 for Pants A, B and C, respectively).

Durability: There were no differences found in ratings of durability among the three pant types. However, the garment by gender interaction term was significant (F = 7.91 (2,544) p<0.001). That is, men's preference scores were lower for Pant C compared to those of the females (Males $\bar{x}$ = 3.32, 3.36, 3.22 for Pant A, B, and C respectively; Females $\bar{x}$ = 3.06, 3.17, 3.31). These results suggest that, on average, male subjects viewed Pants A and B as being more durable, while the females viewed Pant C as more durable. All numerical mean scores, however, correspond to the verbal label *durable*.

Ease of Care: Mean ratings for the ease of care after laundering differed significantly by garment (F = 50.11 (2,558)p<0.001). Pant C received a higher rating than did Pants A or B ($\bar{x}$ = 3.63, 3.66, and 3.95). Overall, Pant C was viewed as maintaining its appearance *well* after laundering; while on average, the other two pants were viewed as maintaining their appearance between *OK* and *Well*. There was, however, a significant interaction between gender and garment type (F = 19.04 (2,558) p<0.001). That is, the mean female score was lower than that of the males for Pants A and B ($\bar{x}$ = 3.25, 3.38, respectively); however, the mean female score for Pant C was higher than that of the males ($\bar{x}$ Male = 3.91, $\bar{x}$ Female = 4.13).

Laundering Frequency: There was no difference in the frequency with which subjects laundered the three types of pants.

Use of Shipboard Laundering: Table 34 presents subjects' estimates of the frequency with which the garments were shipboard laundered. Over 50% of subjects never shipboard laundered their pants.

TABLE 34

Percentage of Time Garments Shipboard Laundered

	100%	**75%**	**66%**	**50%**	**25%**	**Never**
	%	**%**	**%**	**%**	**%**	**%**
Midpoint	10.1	7.6	4.7	10.1	7.9	59.7
Endpoint	14.1	5.8	4.7	11.6	7.2	56.7

Comfort

Table 35 presents the mean ratings of comfort - *overall* and in *hot and cold conditions*

Scale:

Very Uncomfortable	Uncomfortable	Acceptable	Comfortable	Very Comfortable
1	**2**	**3**	**4**	**5**

TABLE 35

Mean Comfort Ratings

	Pant A		**Pant B**		**Pant C**	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**
Conditions	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$
Hot	3.58	3.34	3.58	3.25	3.55	3.75
Cold	3.87	3.62	3.95	3.79	3.55	3.77
Overall	3.82	3.62	3.82	3.64	3.63	3.85

Hot Conditions: Mean ratings for comfort differed significantly by garment (F = 6.17 (2,544) p<0.0025). Pant C received a higher average rating than did Pant A, and Pant A received a higher average rating than Pant B ($\bar{x}$ = 3.54, 3.51, and 3.59, respectively). Mean comfort ratings also differed by data collection (F = 16.67 (1,272) p<0.001). The endpoint collection was lower than the midpoint ($\bar{x}$ = 3.65, 3.45 mid- and endpoint, respectively). There was also a significant interaction between gender and garment type (F = 8.03 (2,544) p<0.001). That is, females rated Pants A and B lower than did males ($\bar{x}$ = 3.34, 3.25 respectively), but they rated Pant C higher than did the males ($\bar{x}$ Male = 3.55, $\bar{x}$ Female = 3.75).

Cold Conditions: Mean ratings for comfort for all three pants did not differ significantly. There was, however, a significant interaction between gender and garment type (F = 8.03 (2,544) p<0.001). Specifically, males rated Pant C significantly lower than did females.

Overall: Mean ratings for overall comfort did not differ significantly among the three pant types. However, females rated Pants A and B lower, and Pant C higher than did males (F = 8.56 (2,544) p<0.001). In addition, the mean ratings for Pants A and B decreased by an average of 0.2 scale points from the midpoint to the endpoint, while the mean rating for Pant C decreased by only 0.05 scale points. These differences were significant (F = 8.32 (2,544) p<0.001).

Overall

The mean overall ratings for each garment are presented in Table 36

Scale:

Very Poor	Poor	Fair	Good	Very Good
1	2	3	4	5

TABLE 36

Overall Pant Ratings

	Pant A		Pant B		Pant C	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**
	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$
Overall	4.13	3.76	4.19	3.87	3.94	4.24

Mean overall ratings did not differ significantly, and were all around the rating of *good.* However, the interaction term gender by garment was, significant ($F = 14.66$ $(2,558)$ $P<0.001$). That is, males rated Pants A and B higher than females, but rated Pant C lower than females (male $\bar{x} = 4.13$, 4.19, and 3.94, respectively; female $\bar{x} = 3.76$, 3.87, and 4.24, respectively).

Comparison

Subjects were asked to rank each of the garments along four factors: fit of pants, comfort of pants, durability of pants, and appearance of pants. Table 37 presents frequencies of rank for each garment, broken out by gender and data collection.

TABLE 37

Frequencies of Pant Number 1 Rankings

%	Pant A			Pant B			Pant C		
Midpoint	**M**	**F**	**All**	**M**	**F**	**All**	**M**	**F**	**All**
Fit	68.1	49.1	64.5	64.7	47.3	61.3	52.2	64.8	54.5
Comfort	70.6	48.1	66.3	65.4	42.6	61.1	49.1	64.2	51.9
Durability	68.7	51.9	65.5	71.2	46.3	66.4	47.8	69.8	51.9
Appearance	60.9	43.4	57.7	61.2	41.5	57.5	53.4	65.4	55.6
Endpoint									
Fit	66.0	45.5	62.1	57.9	38.3	54.3	51.7	72.7	55.8
Comfort	63.7	47.3	60.6	59.0	37.5	54.8	50.2	78.2	55.6
Durability	64.5	38.2	59.5	64.5	40.0	59.9	54.3	76.4	58.6
Appearance	59.6	42.6	56.4	57.0	43.6	54.5	56.8	77.8	60.8

The rank data were subjected to Friedman ANOVAs. For the midpoint, the rank distribution for each pant were significantly different for *fit*, *comfort*, and *durability* (χ^2 = 13.27, 15.55, and 16.08, respectively (df = 2) p<0.002). Pant A received the top ranks for the *fit* and *comfort*; Pant B received the most top ranks for *durability*. Rank distributions were not significantly different for *appearance*.

Comparison to Dungaree Uniform

Table 38 lists the mean ratings for comparing subjects' favorite candidate pant to the current dungaree uniform in four areas. The ratings between the mid- and endpoints were not significantly different. All ratings fell between *Like Current Less* than the most liked candidate pant. These results, however, were more dramatic when the frequencies of responses are considered. Table 39 lists the frequencies for the endpoint data collection.

Scale:

Like **Current** Much Less	Like **Current** Less	Like **Current** Same	Like **Current** More	Like **Current** Much More
1	**2**	**3**	**4**	**5**

TABLE 38

Mean Comparison Rating

	Mid	**End**
	$\bar{x}$	$\bar{x}$
Fit of Pants	2.71	2.57
Comfort	2.80	2.59
Durability	2.77	2.61
Appearance	2.80	2.53

The ratings between the mid- and endpoints were not significantly different. All are between *Like Current Less* than the most liked test pant. These results, however, are more dramatic when the frequencies of responses are viewed. Table 39 lists the frequencies for the endpoint data collection.

TABLE 39

Overall Pant Ratings

Rank	1	2	3	4	5
Fit of Pants	37.5	15.2	16.9	10.1	20.3
Comfort	36.5	16.9	16.2	8.8	21.6
Durability	35.8	14.5	19.6	10.1	19.9
Appearance	41.2	14.9	13.2	8.4	22.3

These data suggest that for all criteria, over 50% of the subjects preferred the candidate pants over than the current This could be any of the three candidate pants, as the question asked subjects to compare their *most favored (candidate) pant* to the current dungarees. Approximately 30% of subjects favored the current dungaree uniforms for each criteria. The remaining 20% stated they liked both the candidate and current pants equally.

General Questions

Test participants were asked whether or not they wanted the current *bell bottom* pants retained in the system, and if they desired a prescribed method of rolling their shirt sleeves. All subjects (n=501) were included in the analyses. Table 40 lists the frequencies of response for both questions.

TABLE 40

Frequencies of Response

	Midpoint		Endpoint	
	% YES	**% NO**	**% YES**	**% NO**
Retain Bell Bottoms	20.2	79.7	21.6	78.4
Prescribed Sleeve Roll	57.0	43.0	61.2	38.8

Over 78% of the subjects responded that they did not want to retain the bell bottoms. Both the midpoint and endpoint data were subjected to Chi squared analyses. The number of *Yes* versus *No* responses was significantly different for both data points (χ^2 (1) = 818.77, 150.37 mid- and endpoints respectively p<0.001). This indicates that at both data collections significantly more subjects stated that the bell bottoms should not be retained.

Fifty-seven percent of subjects at the midpoint and 61% of subjects at the endpoint were in favor of a prescribed method of rolling their shirt sleeves. The number of *Yes* and *No* at both data points were significantly different (χ^2 (1) = 9.19, 24.50 for the mid- and endpoints respectively p<0.0025). This suggests that significantly more subjects were in favor of a prescribed method of rolling the sleeves than were not.

Further Analyses

Several further analyses were carried out on selected key portions of the data. Age was added as a covariate to the four factor ANOVA design used for the shirt and pant analyses. Adding age as a covariate to these analyses was done to determine whether any significant differences between means could have been explained by age. The analyses were run for *overall fit preference*, *design rating*, *overall comfort*, and *overall rating*. There was no systematic affects of age upon the results.

In an effort to distinguish which pants male subjects preferred at the end of the study, the ANOVA design was simplified by removing the female test participants from the analysis. A one factor within-subjects ANOVA, with garment serving as the within subjects factors was conducted on endpoint data for *overall fit preference* ratings and the *overall rating*.

TABLE 41

Overall Pant Ratings

		Pant A	Pant B	Pant C
		$\bar{x}$	$\bar{x}$	$\bar{x}$
Overall Fit	(1=Dislike Very Much, 5=Like Very Much)	**4.18**	**4.18**	**4.01**
Overall Ratings	(1=Very Poor, 5=Very Good)	**4.07**	**4.12**	**3.87**

Table 41 lists the mean rating scores for *overall fit preference* and *overall rating* for each pair of pants. No significant differences were found between the ratings for any of the pants for either overall fir or overall rating. Thus, when the males are considered alone, at the last data collection point, there is no difference any of the pants.

Discussion

From the initial issue of 1278 uniforms, 501 subjects completed surveys from all three phases. The East and West Coast ships returned approximately 50% of the surveys. Thirty percent of the surveys were returned by female sailors. The returned surveys do not appear to be biased to any one coast, or to either male or female populations, given that uniforms were only issued to 354 females (28% of the issue population). Ethnographic background of participants appears to be an accurate representation of the overall Navy population. Thus, the subject pool used in the analyses appears to be representative of the general Navy population. This fact enables a fairly confident extrapolation of the findings from this subject pool to the entire Navy.

Shirts

It was important in the analyses to distinguish between subject's whose shirts fit and, those who were issued shirts but found that they did not fit. Subjects with "non-fitting" shirts were dropped from the analysis as it would have been impossible to tell if their ratings and opinions were due to the shirt or the fact that the shirt did not fit. These data would confound any true differences or preferences amongst the shirts. Seventy percent of the subjects had two shirts that fit. The remaining 30% of the subjects either had one shirt, or both which did not fit. This fit rate should be compared to that of the current chambray shirt to assess whether they are different.

In many instances, mean ratings were found to be significantly different, even after adjusting the alpha level. The statistics often had enough power to distinguish between tenths of scale points. This level of distinction is too fine to lead to *practical* differences between shirts. Thus, it becomes necessary to define what is a practical difference. In most cases, one quarter of a scale point will be considered a practical difference. That is, when two mean ratings are different by more than 0.25 scale points, the difference will show a real tendency of subjects to prefer one garment or attribute of a garment over the other. Differences which were smaller than this will not be explained in any depth in the discussion that follows since they hold little practical importance.

The five main areas of the survey will be discussed separately.

Fit of Shirt

The fit of the shoulders, chest, arms, neck, stomach, and overall-fit of the shirts were on average, described as *Regular*. Mean ratings for the *like* or *dislike of the fit* were all positive and in general, fell around the *Like Moderately* rating point. Shirt C, overall, and for the shoulders, chest, arms, neck, and stomach, received higher ratings than Shirt A. The differences between all these ratings are close 0.25 scale points and would suggest a real preference towards Shirt C. There was no evidence from the data that shrinkage due to laundering affected the fit over time.

Design of Shirts

Four areas were examined to investigate the design of the shirts. The *overall look* of both shirts were rated favorably, with average ratings above *Like Moderately*. Over 93% of subjects stated that they had no restrictions to their activities. Those subjects that stated having some restriction, either had fit problems or their work necessitated wearing other garments. Eighty-seven percent of the subjects stated that both shirts were *suited* to their particular job. Shirt pockets were, on average, rated *Fairly Easy*. Thus, the design of the shirts met with favorable responses and the data indicate that they do not cause any major problems in the day-to-day functioning of a sailor.

Durability

Wear time for both shirts was fairly high - 52 days for Shirt A/B and 46 days for Shirt C; although there was a difference between these two times, the period is large enough for durability to be assessed. Although both shirts were rated as being *Durable*, Shirt C, on average, was viewed as being more durable than Shirt A/B.

Ease of care proved to be a distinguishing factor between the two shirts. Subjects were asked to rate how well the shirts maintained their appearance after laundering. Shirt A/B received an average numerical rating of 2.28 which corresponds to the verbal rating of *Poorly*, while Shirt C's average rating of 3.91 corresponds to the verbal rating of *Well*. The mean rating of Shirt A/B was in the negative portion of the scale, and was over 1½ scale points lower than Shirt C. It appears, therefore, that Shirt A/B does not maintain its appearance very well after it has been laundered.

Comfort

In hot conditions Shirt A/B received a mean rating for comfort in the negative portion of the scale ($\bar{x} = 2.73$) (less than *acceptable*), while Shirt C received a mean rating in the positive end of the scale ($\bar{x} = 3.28$) (above *acceptable*). This difference was accentuated at the endpoint. Shirt A/B's mean rating was 2.55 while Shirt C's was only 3.18. This decrease between data collections would be expected, as the midpoint data collection was conducted in the spring, while the endpoint collection was conducted in the summer. Thus, hotter weather would tend to exaggerate the difference in thermal comfort.

In cold conditions, both shirts were rated equally well for comfort, above the *acceptable* rating.

For overall comfort, Shirt C was preferred over Shirt A/B. Both ratings were however, above *acceptable*. The overall mean ratings for comfort dropped from the midpoint to the endpoint, again this was probably a function of the warmer weather.

Overall

The final overall rating of the survey distinguished well between the two shirts. Shirt A/B received a mean overall rating of 3.16 (*Fair*) while Shirt C received an overall mean rating of 3.91 (*Good*). When male and female responses were also examined, the female mean overall scores accentuate the difference. Shirt A/B received a rating lower than *Fair*, while Shirt C received a rating higher than *Good.* The male mean overall score still favored Shirt C but the margin of difference was reduced.

Conclusion

Clearly, the data indicate a preference for Shirt C. Although all fit data indicate that both shirts fit well, Shirt C consistently received statistically higher ratings in all of the fit areas. Similarly, even though both shirts have good average durability ratings (around *durable)*, Shirt C again, had a significantly higher rating.

In addition, Shirt A/B data indicate that subjects found two negative attributes of the shirt. The ease of care data suggest that Shirt A/B maintained its appearance *poorly* after laundering. This is not a trivial problem since excess time spent on working with the shirt to obtain a professional military appearance could lead to a drop in productivity. Shirt A/B was also found to be slightly uncomfortable in hot weather, and its overall rating of comfort was significantly lower than that of Shirt C. Moreover, this was confirmed by the direct ranking of the two shirts. For both durability and appearance, Shirt C received significantly more number one rankings. This was especially true for appearance.

Shirt C appears to be an acceptable alternative to the current chambray shirt. All data for Shirt C were positive, and in general, it appeared to be well-liked. Sailors compared their most favored test shirt to the current dungaree shirt. Because Shirt C always received the higher ratings, it can be assumed that it was the shirt which was compared to the dungaree shirt most often.

However, the mean ratings for this comparison do not suggest that test participants favor Shirt C to the current chambray shirt. Upon examining the frequencies of response, 35% of the subjects said they preferred their favored test shirt, while an equal percentage preferred the current shirt. These data suggest that although Shirt C always received positive ratings, it was, at best, viewed on par with the current shirt.

Pants

The fit rate for the pants was fairly low, with less than 60% of all subjects stating that they did not fit into one or more of the pants. Upon further examination, there was a significant difference in the fit rate of males and females. Approximately 69% of males were fit into all three pants, while only 37% of females were successfully fit into all three.

Upon examination of the fit data, the main problem of fit for females occurred with Pant C. Females were fit almost as successfully as males into Pants A and B, but only 53% of the female subjects were fit into Pant C. The most probable cause of this poor fit rate was the lack of correct sizes for female subjects at issue. Although a complete range of sizes was procured for the test, there were insufficient quantities of smaller sizes. This created a shortage in sizes, and some subjects could not be fit with their ideal size. The best fit possible was sought, but was not always achieved.

On the whole, the reasons male and female stated for not fitting into Pants A and B were the same - about 60% said the pants were too tight. In contrast, the reasons given by males and females were different for Pant C. Approximately 45% of male and only 21% of female subjects stated Pant C was too tight; while 39% of males 59% of females they were too loose.

A difference was found in the pattern of self- reported and issued sizes between the *pants*. With respect to Pants A and B, male issued sizes were, on average, 0.2" greater than self-reported sizes; and female issued sizes were, on average, one size greater. For Pant C, male self-reported and issue sizes did not differ, while the female issued size *decreased* by approximately 2 sizes. Comments taken from the surveys suggest that the pants were tight in the waist but baggy and loose around the hips and seat areas.

<u>*Fit of Pants*</u>

The overall length and crotch length of all the pants were rated as being *Just Right*. The fit of all the pants for the waist, seat area, thigh and overall were described as being a *Regular Fit*. The female score, however, for Pant C for the seat area, thigh, and overall fit was significantly different from the other scores. The female mean rating for Pant C was higher, suggesting that the fit of Pant C was slightly baggier than a *Regular Fit*.

In general, subjects rated their like or dislike of all pants as *Like Moderately*. This was the case for the *overall rating* and for the *waist, seat area, and thigh ratings*. There were, however, no practical differences among the pants.

The female rating for the waist did change from the midpoint to the endpoint ($\bar{x} = 4.19$ and 3.67, respectively). This was quite a large change in perception of the fit. The midpoint rating was above *Like Moderately,* while the endpoint rating is between *Neither Like nor Dislike* and Like *Moderately*. This change could possibly be due to the effect of shrinkage in the garments from laundering.

Design of Pants

Test participants stated they liked the overall look of the pants *Moderately*. This was true for all pants. Similarly, the design of the pant legs also had a mean rating of *Moderately.* When the male and female scores were compared for the *overall look*, males preferred Pants A and B over Pant C, while females preferred Pant C over Pants A and B.

Approximately 95% of the subjects found that they could accomplish all their daily activities in any of the pants, and over 91% stated that the garments were suited to their job. Comments from those who could not accomplish their daily tasks indicated that either specialized clothing was needed, or that there was a fit problem with a garment. Over 81% of subjects stated that they were able to easily stencil or attach their name tag to the pants.

Front and back pockets on all pants were acceptable to test participants, receiving ratings above *Like Moderately.*

Durability

Total wear time, which was calculated by the number of test weeks multiplied by the number of days in a week that a garment was worn, differed among the pants (52 Days, 53 Days, and 47 Days for Pants A, B and C, respectively). This difference in wear time may be attributable to two factors: Pants A and B may have been favored more so they were worn more; or as there was no set wear rotation plan, Pant C may have been last in the wear rotation and was therefore worn for less time each week. All pants had mean ratings of durability above *Durable*. However, males rated Pants A and B as being more durable than Pant C, while the reverse was true for females (they rated Pant C more durable).

All pants had positive ratings for maintaining their appearance after laundering; however, a significant difference was found among the pants. Pants A and B had lower mean ratings than did Pant C. Again, there appears to be a gender difference, with females rating C higher than males.

Little shipboard laundering was done throughout the study. Over 57% of subjects stated that they never used the shipboard laundry, while only 10% to 14% used the shipboard laundry all the time.

Comfort

For comfort in *hot and cold conditions* and *overall comfort*, ratings were all positive, and any differences had no practical meaning. However, when male and female ratings were closely examined, differences were evident. In hot conditions, the male scores were the same for all pants. The female scores, however, were different: for Pants A and B, ratings were close to *Acceptable* while, the rating for Pant C was close to *Comfortable*. There was a half scale point of

difference between the ratings for Pants A and B, and Pant C. This suggests that this difference is quite a strong effect. Thus, the females prefer the comfort of Pant C in hot weather, while the males find the comfort of all the pants the same.

Overall Rating

All pants received a mean overall rating of *Good*. Males and females were, again, split over which pant they liked best. Males preferred Pants A and B, with ratings above *Good*; while the female score was below *Good*. In contrast, the male scores for Pant C were below *good* and the female scores above the *Good* marker. These data indicate that, overall, male subjects preferred either Pants A or B, and the females preferred Pant C.

Conclusion

Examining the overall data for each pant type, there is very little which distinguishes any one of the three. All pants fit well in all areas. All received good durability ratings, and pockets which were fairly easy to use. All were comfortable in both hot and cold environments, and received similar overall ratings. There were two areas where Pant C was preferred over the other two pants, albeit slightly. In maintaining its appearance after laundering, Pant C was preferred over Pants A and B. Subjects also found it easier to stencil or attach their name to Pant C.

When male and female scores were viewed separately there was a divergence of opinion as to which pant was best. Males preferred Pants A and B over Pants C along the following factors: *overall look*, *durability*, *overall comfort*, and in their final *overall rating*. In contrast, females preferred Pant C over Pants A and B along the following factors: *overall design*, *overall look*, *overall comfort*, *comfort in hot weather*, and in their final *overall rating*.

The ranking data confirm this preference split between the males and females. For both data collection points, there were more top rankings given by males for Pants A and B than for Pant C. For females, Pant C received more top rankings than did Pants A and B. Although the combined male and female ranking data have significantly more number one ranks for Pants A and B, this is biased by the larger number of males serving as test participants.

All three pants seem to be acceptable alternatives to the current dungaree pant, because in general, the pants were all rated positively. When the subjects' most favored pant was compared to the current dungarees, the mean comparison ratings were between 2.7 and 2.8 for the four areas of comparison. This suggests that the current dungarees were liked less than the candidate uniforms. When the frequencies of response were examined, over 50% of the subjects stated they liked the current uniform less than their favored test uniform, with only 30% of the respondents stating that they like the current dungarees better.

The comparison data suggest that any of the three pants would be a suitable replacement to the dungaree uniform. Males favored the choice of pant A or pant B, while females favored Pant C.

Recommendations

Although Shirt C received positive ratings, it showed no clear advantage over the current chambray shirt. In fact, it was rated lower than the current shirt. It therefore appears that the current shirt should be retained.

All Pants would make good replacements for the current dungaree pant. They all appeared to wear well over the six-month time period, and were rated as maintaining their appearance well after laundering. The pant pockets were easy to use, and over 80% of the subjects stated that the pants were suited to their job. Subjects rated the overall look between *like moderately* and *like very much*. Most importantly, when compared to the current dungarees, over half the subjects chose new pants over the current bell bottom dungarees. If a choice between the pants need be made Pant C should be chosen above Pants A and B, assuming that the female fit problem was due to a lack of particular sizes.

On many factors the males showed no clear preference for any of the three candidates, while the females almost always preferred Pant C. Therefore, it would seem that Pant C is the best alternative since it is a clear winner among the women, while the men do not have a strong preference for any of the candidates.

Appendix A: COTS Issue Sheet

Utility Uniform

(Issue Sheet)

1. Name: ____________________

2. DOB: Day ____ / Month ____ / Year ____

3. Last Four: _ _ _ _

4. Rate: ____________________

5. Ship: ____________________

6. Division: ____________________

7. Sex: (Check or X)
- ◯ 1 Male
- ◯ 2 Female

8. Race: (Check or X)
- ◯ 1 American Indian / Alaskan Native
- ◯ 2 Asian / Pacific Islander
- ◯ 3 Black (not of Hispanic Origin)
- ◯ 4 Hispanic
- ◯ 5 Mixed
- ◯ 6 White (not of Hispanic Origin)
- ◯ 7 Other:____________________

SUBJECT'S CLOTHING SIZES

Shirt Sizes

9. Shirt Size: (Check or X)
- ◯ 1 _____
- ◯ 2 XXS
- ◯ 3 XS
- ◯ 4 S
- ◯ 5 M
- ◯ 6 L
- ◯ 7 XL
- ◯ 8 XXL
- ◯ 9 _____

10. Collar: __________ Inches

11. Sleeve: __________ Inches

Pant Sizes

12. Waist: __________ Inches

13. Inseam: __________ Inches

14. Length: (Check or X)
- ◯ 1 X Short
- ◯ 2 Short
- ◯ 3 Medium
- ◯ 4 Long
- ◯ 5 X Long

15. Female Size: __________

ISSUED SIZES

Shirts

A

(Poly Cotton Poplin Shirt)

16. Shirt Size: (Check or X)
- ◯ 1 ____
- ◯ 2 XXS
- ◯ 3 XS
- ◯ 4 S
- ◯ 5 M
- ◯ 6 L
- ◯ 7 XL
- ◯ 8 XXL
- ◯ 9 ____

17. Collar: ________ Inches
18. Sleeve: ________ Inches

19. Satisfactory fit obtained? (Check or X)
- ◯ 1 YES
- ◯ 2 NO

B

(100% Cotton Chambray Shirt)

20. Shirt Size: (Check or X)
- ◯ 1 ____
- ◯ 2 XXS
- ◯ 3 XS
- ◯ 4 S
- ◯ 5 M
- ◯ 6 L
- ◯ 7 XL
- ◯ 8 XXL
- ◯ 9 ____

21. Collar: ________ Inches
22. Sleeve: ________ Inches

23. Satisfactory fit obtained? (Check or X)
- ◯ 1 YES
- ◯ 2 NO

Pants

A

(Poly Cotton Twill Pant)

24. Waist: ________ Inches
25. Inseam: ________ Inches

26. Length: (Check or X)
- ◯ 1 Xshort
- ◯ 2 Short
- ◯ 3 Medium
- ◯ 4 Long
- ◯ 5 Xlong

27. Female Size: ________

28. Satisfactory fit obtained? (Check or X)
- ◯ 1 YES
- ◯ 2 NO

B

(100% Cotton Denim Pant)

29. Waist: ________ Inches
30. Inseam: ________ Inches

31. Length: (Check or X)
- ◯ 1 XShort
- ◯ 2 Short
- ◯ 3 Medium
- ◯ 4 Long
- ◯ 5 XLong

32. Female Size: ________

33. Was a satisfactory fit obtained? (Check or X)
- ◯ 1 YES
- ◯ 2 NO

34. Notes and Comments:-

Appendix B: COTS Wear Test Questionnaire

Utility Uniform

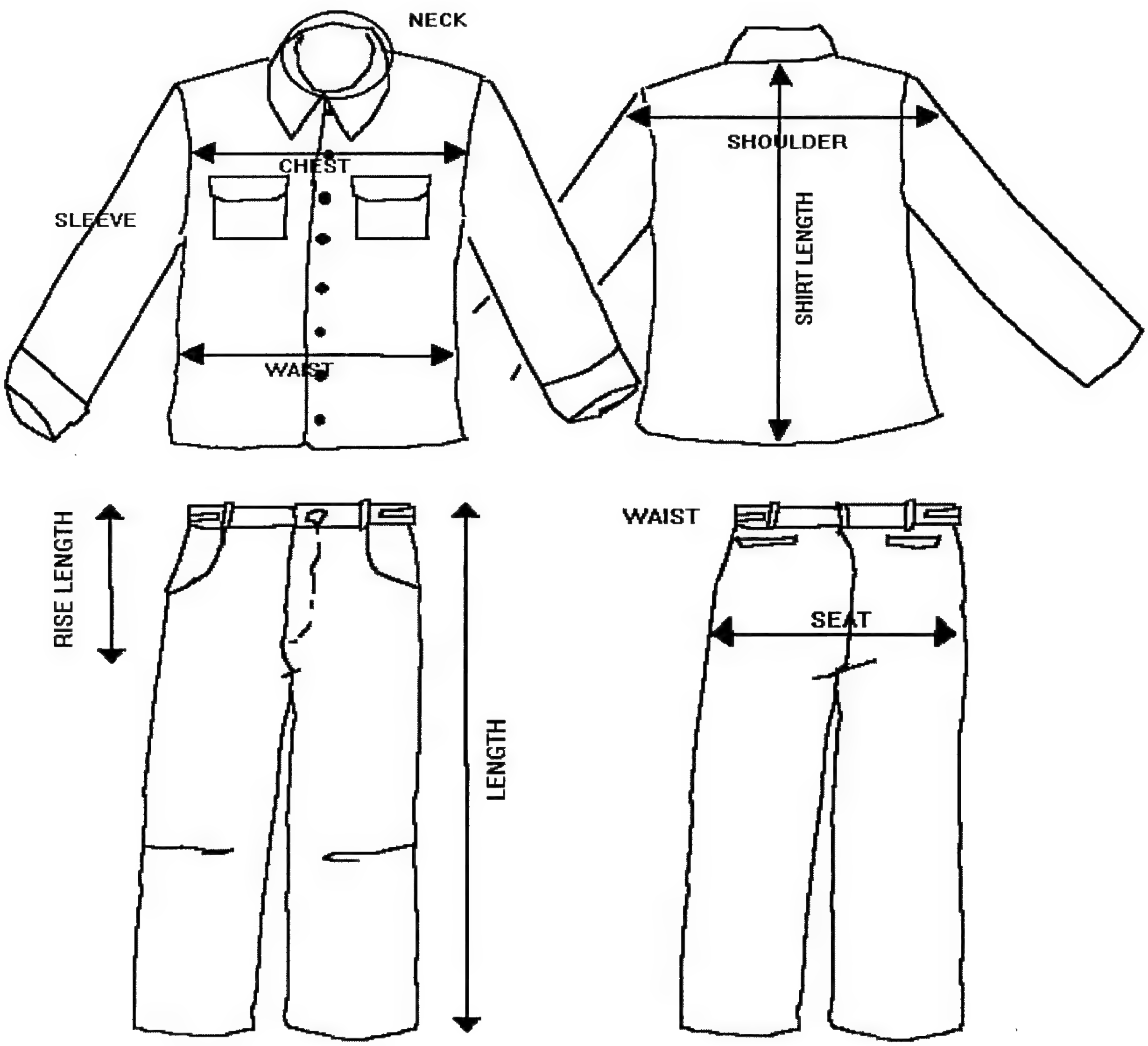
(User Survey)

1. Name: ______________________ 2. DOB: ____/____/____ (Day Month Year)

3. SSN: _ _ _ _ (Last Four Numbers) 4. Date: ____/____/____ (Day Month Year)

Thank you for your participation in this study. Answer each question as fully as possible for both types of uniform (shirts and pants). Please provide comments where asked for. If a question does not have comment space, reserve your comments until question 25.

For questions which ask about fit, please refer to the illustrations below.



Preference of Fit

q1. For each garment please rate **how much you like the fit** for the areas listed, using the scale.

Scale:

Dislike Very Much	Dislike Moderately	Neither Like nor Dislike	Like Moderately	Like Very Much
1	2	3	4	5

Shirt A (Poplin)

5a. Overall Fit	1	2	3	4	5	(Circle or X)
6a. Across Shoulders	1	2	3	4	5	
7a. Chest	1	2	3	4	5	
8a. Sleeve	1	2	3	4	5	
9a. Neck	1	2	3	4	5	
10a. Waist	1	2	3	4	5	

Shirt B (Chambray)

5b. Overall Fit	1	2	3	4	5	(Circle or X)
6b. Across Shoulders	1	2	3	4	5	
7b. Chest	1	2	3	4	5	
8b. Sleeve	1	2	3	4	5	
9b. Neck	1	2	3	4	5	
10b. Waist	1	2	3	4	5	

Pant A (Twill)

11a. Overall Fit	1	2	3	4	5	(Circle or X)
12a. Waist	1	2	3	4	5	
13a. Seat Area	1	2	3	4	5	
14a. Length	1	2	3	4	5	

Pant B (Denim)

11b. Overall Fit	1	2	3	4	5	(Circle or X)
12b. Waist	1	2	3	4	5	
13b. Seat Area	1	2	3	4	5	
14b. Length	1	2	3	4	5	

Description of Fit

q2. For each garment please **describe the fit** for the areas listed, using the rating scale.

Scale:				
Very Tight	Moderately Tight	Neither Tight nor Loose	Moderately Loose	Very Loose
1	2	3	4	5

Shirt A (Poplin)

15a. Overall Fit	1	2	3	4	5	(Circle or X)
16a. Across Shoulders	1	2	3	4	5	
17a. Chest	1	2	3	4	5	
18a. Sleeve	1	2	3	4	5	
19a. Neck	1	2	3	4	5	
20a. Waist	1	2	3	4	5	

Shirt B (Chambray)

15b. Overall Fit	1	2	3	4	5	(Circle or X)
16b. Across Shoulders	1	2	3	4	5	
17b. Chest	1	2	3	4	5	
18b. Sleeve	1	2	3	4	5	
19b. Neck	1	2	3	4	5	
20b. Waist	1	2	3	4	5	

Pant A (Twill)

21a. Overall Fit	1	2	3	4	5	(Circle or X)
22a. Waist	1	2	3	4	5	
23a. Seat Area	1	2	3	4	5	
24a. Length	1	2	3	4	5	

Pant B (Denim)

21b. Overall Fit	1	2	3	4	5	(Circle or X)
22b. Waist	1	2	3	4	5	
23b. Seat Area	1	2	3	4	5	
24b. Length	1	2	3	4	5	

Length

q3. For each garment please **evaluate the length** for the areas listed, using the scale below.

Scale:				
Much too Short 1	Slightly too Short 2	Just Right 3	Slightly too Long 4	Much too Long 5

	Shirt A (Poplin)				
25a. Sleeve Length	1	2	3	4	5
26a. Overall Length	1	2	3	4	5
	Shirt B (Chambray)				
25b. Sleeve Length	1	2	3	4	5
26b. Overall Length	1	2	3	4	5
	Pant A (Twill)				
27a. Leg Length	1	2	3	4	5
28a. Rise (Crotch Length)	1	2	3	4	5
	Pant B (Denim)				
27b. Leg Length	1	2	3	4	5
28b. Rise (Crotch Length)	1	2	3	4	5

(Circle or X)

(Circle or X)

Design

q4. Please rate how you like the **overall look** of each garment.

Shirt	Really Dislike	Dislike	Fair	Like	Really Like	Please explain
29a. **A** (Poplin)	○ 1	○ 2	○ 3	○ 4	○ 5	30a. ______
29b. **B** (Chambray)	○ 1	○ 2	○ 3	○ 4	○ 5	30b. ______
Pant						
31a. **A** (Twill)	○ 1	○ 2	○ 3	○ 4	○ 5	32a. ______
31b. **B** (Denim)	○ 1	○ 2	○ 3	○ 4	○ 5	32b. ______

q5. Please rate how you like the design of the pant legs.

Pant	Really Dislike	Dislike	Fair	Like	Really Like	Please explain
33a. **A** (Twill)	○ 1	○ 2	○ 3	○ 4	○ 5	34a. ______
33b. **B** (Denim)	○ 1	○ 2	○ 3	○ 4	○ 5	34b. ______

q6. Please rate how easy it is to stencil or attach your name tag to each pair of pants.

Pant	Very Difficult	Somewhat Difficult	Fair	Somewhat Easy	Very Easy	Please explain
35a. **A** (Twill)	○ 1	○ 2	○ 3	○ 4	○ 5	36a. ______
35b. **B** (Denim)	○ 1	○ 2	○ 3	○ 4	○ 5	36b. ______

Restriction in Activities

q7. Does the fit of the following garments restrict or hinder any of your daily activities?

Shirt	No	A Little	Some	A Lot	If YES then please describe activity
37a. **A** (Poplin)	◯1	◯2	◯3	◯4	38a. ______
37b. **B** (Chambray)	◯1	◯2	◯3	◯4	38b. ______
Pant					
39a. **A** (Twill)	◯1	◯2	◯3	◯4	40a. ______
39b. **B** (Denim)	◯1	◯2	◯3	◯4	40b. ______

Suitability

q8. Please rate how **suited** each garment is for the work **you** do?

Shirt	Very unsuited	Somewhat unsuited	OK	Somewhat suited	Very suited	Why?
41a. **A** (Poplin)	◯1	◯2	◯3	◯4	◯5	42a. ______
41b. **B** (Chambray)	◯1	◯2	◯3	◯4	◯5	42b. ______
Pant						
43a. **A** (Twill)	◯1	◯2	◯3	◯4	◯5	44a. ______
43b. **B** (Denim)	◯1	◯2	◯3	◯4	◯5	44b. ______

Pockets

q9. Please rate how **easy** the pockets are to use for your regular duties?

Shirt	Very Difficult	Somewhat Difficult	Fair	Somewhat Easy	Very Easy
45a. **A** (Poplin)	◯1	◯2	◯3	◯4	◯5
45b. **B** (Chambray)	◯1	◯2	◯3	◯4	◯5
Pant					
46a. **A** (Twill)	◯1	◯2	◯3	◯4	◯5
46b. **B** (Denim)	◯1	◯2	◯3	◯4	◯5

q10. Please choose all the reasons that best describe why your pockets are easy/not easy to use.

Shirt	Big	Small	High	Low	Deep	Shallow	Tight	Loose	Angle
47a. **A** (Poplin)	◯1	◯2	◯3	◯4	◯5	◯6	◯7	◯8	◯9
47b. **B** (Chambray)	◯1	◯2	◯3	◯4	◯5	◯6	◯7	◯8	◯9
Pant									
48a. **A** (Twill)	◯1	◯2	◯3	◯4	◯5	◯6	◯7	◯8	◯9
48b. **B** (Denim)	◯1	◯2	◯3	◯4	◯5	◯6	◯7	◯8	◯9

Durability

q11. Please indicate whether you have experienced shrinkage, staining or fading in each garment.

		Shrinks	Stains	Fades	Please Explain
49a. Shirt	**A** (Poplin)	◯1	◯2	◯3	50a. ______
49b.	**B** (Chambray)	◯1	◯2	◯3	50b. ______
51a. Pant	**A** (Twill)	◯1	◯2	◯3	52a. ______
51b.	**B** (Denim)	◯1	◯2	◯3	52b. ______

Durability Continued

q12. How durable are the following garments to rips, tears, abrasions, or failures in seams, fasteners, buttons etc.?

Shirt	Not Durable		Fair		Very Durable	Please explain.
53a. **A** (Poplin)	◯1	◯2	◯3	◯4	◯5	54a. ________
53b. **B** (Chambray)	◯1	◯2	◯3	◯4	◯5	54b. ________
Pant						
55a. **A** (Twill)	◯1	◯2	◯3	◯4	◯5	56a. ________
55b. **B** (Denim)	◯1	◯2	◯3	◯4	◯5	56b. ________

q13. For the following garments please indicate all areas that have any durability problems.

Shirt	Arms	Back	Chest	Collar	Front	Cuff	Pockets	Seams	Buttons
57a. **A** (Poplin)	◯1	◯2	◯3	◯4	◯5	◯6	◯7	◯8	◯9
57b. **B** (Chambray)	◯1	◯2	◯3	◯4	◯5	◯6	◯7	◯8	◯9

Pant	Legs	Knee	Front	Seat	Waist	Pockets	Seams	Zippers	Buttons/ Snaps	Crotch
58a. **A** (Twill)	◯1	◯2	◯3	◯4	◯5	◯6	◯7	◯8	◯9	◯10
58b. **B** (Denim)	◯1	◯2	◯3	◯4	◯5	◯6	◯7	◯8	◯9	◯10

Frequency of Wear

q14. Have you been wearing the uniforms since the beginning of the test period until this point?

			If NO - How many weeks have you worn them?
59a. Uniform A	◯1 Yes	◯2 No	60a. ________
59b. Uniform B	◯1 Yes	◯2 No	60b. ________

q15. How many days do you wear each uniform per week?

61a. Uniform A _____ Days per Week

61b. Uniform B _____ Days per Week

Ease of Care

q16. Please rate how well each garment maintains its appearance after laundering.

Shirt	Very Poorly	Poorly	OK	Well	Very Well
62a. **A** (Poplin)	◯1	◯2	◯3	◯4	◯5
62b. **B** (Chambray)	◯1	◯2	◯3	◯4	◯5
Pant					
63a. **A** (Twill)	◯1	◯2	◯3	◯4	◯5
63b. **B** (Denim)	◯1	◯2	◯3	◯4	◯5

q17. Please estimate the proportion of times your garments were shipboard laundered.

Always					Never	Other
64. ◯1 100%	◯2 80%	◯3 60%	◯4 40%	◯5 20%	◯6 0%	◯7 ___

q18. How often do you launder each uniform?

64a. Uniform **A:** Every _______ Days   64b. Uniform **B:** Every _______ Days

Comfort

q19. For the following conditions please rate how comfortable each garment is to wear.

Scale:

Very Uncomfortable	Uncomfortable	Acceptable	Comfortable	Very Comfortable
1	2	3	4	5

Overall						Reason
65a. Shirt **A**	1	2	3	4	5	66a. ________
65b. **B**	1	2	3	4	5	66b. ________
67a. Pant **A**	1	2	3	4	5	68a. ________
67b. **B**	1	2	3	4	5	68b. ________

When Hot						Reason
69a. Shirt **A**	1	2	3	4	5	70a. ________
69b. **B**	1	2	3	4	5	70b. ________
71a. Pant **A**	1	2	3	4	5	72a. ________
71b. **B**	1	2	3	4	5	72b. ________

When Cold						Reason
73a. Shirt **A**	1	2	3	4	5	74a. ________
73b. **B**	1	2	3	4	5	74b. ________
75a. Pant **A**	1	2	3	4	5	76a. ________
75b. **B**	1	2	3	4	5	76b. ________

Overall

q20. Please give an **overall** rating for each garment.

Shirt	Very Poor	Poor	Fair	Good	Very Good
77a. **A** (Poplin)	◯1	◯2	◯3	◯4	◯5
77b. **B** (Chambray)	◯1	◯2	◯3	◯4	◯5
Pant					
78a. **A** (Twill)	◯1	◯2	◯3	◯4	◯5
78b. **B** (Denim)	◯1	◯2	◯3	◯4	◯5

Comparison

q21. For the following categories please compare the two garments you have been wearing.

Scale: Like **A** Much **LESS** than **B**		Like **A** & **B** Same		Like **A** Much **MORE** than **B**
1	2	3	4	5

79. Fit of Shirt	1	2	3	4	5
80. Fit of Pants	1	2	3	4	5
81. Comfort of Shirt	1	2	3	4	5
82. Comfort of Pants	1	2	3	4	5
83. Durability of Shirt	1	2	3	4	5
84. Durability of Pants	1	2	3	4	5
85. Appearance of Shirt	1	2	3	4	5
86. Appearance of Pants	1	2	3	4	5

(Circle or X)

q22. For the following categories please compare **the garment you liked the most** (A or B) to the **CURRENT utility uniform** (Dungaree Uniform).

Scale: Like **CURRENT** Much **LESS**		Like Same		Like **CURRENT** Much **MORE**
1	2	3	4	5

87. Fit of Shirt	1	2	3	4	5
88. Fit of Pants	1	2	3	4	5
89. Comfort of Shirt	1	2	3	4	5
90. Comfort of Pants	1	2	3	4	5
91. Durability of Shirt	1	2	3	4	5
92. Durability of Pants	1	2	3	4	5
93. Appearance of Shirt	1	2	3	4	5
94. Appearance of Pant	1	2	3	4	5

(Circle or X)

q23. Would you like to see the current "Bell Bottoms" retained on any new utility uniform?

95. ○1 Yes ○2 No 96. Please explain: ____________________

q24. Would you like to see a prescribed method of rolling up shirt sleeves?

97. ○1 Yes ○2 No 98. Please explain: ____________________

q25. Please provide any further comments you may have about the uniforms you have been wearing. If you need extra space please use the back of this survey.

99. ____________________

____

____

____

Appendix C: Example Issue Sheet

Utility Uniform

(Issue Sheet)

1. Name: ____________________

2. DOB: ____/____/____
   Day Month Year

3. SSN: _ _ _ _ (Last Four Numbers)

4. Sex: (Check or X)
   - ◯ 1 Male
   - ◯ 2 Female

5. Phone: (   )   -

6. Rate: ____________________

7. Ship: ____________________

8. Division: ____________________

9. Race: (Check or X)
   - ◯ 1 American Indian / Alaskan Native
   - ◯ 2 Asian / Pacific Islander
   - ◯ 3 Black (not of Hispanic Origin)
   - ◯ 4 Hispanic
   - ◯ 5 Mixed
   - ◯ 6 White (not of Hispanic Origin)
   - ◯ 7 Other:____________________

(Shaded area to be filled in by Issuer)

TEST PARTICIPANT'S SELF REPORTED CLOTHING SIZES

Shirt Sizes

10. Shirt Size: (Check or X)
    - ◯ 1 XXS
    - ◯ 2 XS
    - ◯ 3 S
    - ◯ 4 M
    - ◯ 5 M-L
    - ◯ 6 L
    - ◯ 7 XL
    - ◯ 8 XXL
    - ◯ 9 XXXL
    - ◯ 10 Other

11. Other Size: __________

Pant Sizes

Male

12. Waist: __________ Inches

13. Inseam: __________ Inches

Female

14. Size: __________

15. Length: __________
    (S, R, L, XL)

ISSUED SIZES

Shirts

A/B
(Chambray)

16. Shirt Size: (Check or X)
- ◯ 1 S
- ◯ 2 M
- ◯ 3 M-L
- ◯ 4 L
- ◯ 5 XL
- ◯ 6 XXL

17. Satisfactory fit obtained? (Check or X)
- ◯ 1 YES
- ◯ 2 NO

C
(Poplin)

18. Shirt Size: (Check or X)
- ◯ 1 S
- ◯ 2 M
- ◯ 3 M-L
- ◯ 4 L
- ◯ 5 XL
- ◯ 6 XXL

19. Satisfactory fit obtained? (Check or X)
- ◯ 1 YES
- ◯ 2 NO

Pants

A
(14.5 Oz. Denim Pant)

Male
20. Waist: __________ In.
21. Inseam: __________ In.

OR

Female
22. Size: __________
23. Length: ◯1 R ◯2 L

24. Satisfactory fit obtained? (Check or X)
- ◯ 1 YES
- ◯ 2 NO

B
(11.3 Oz. Denim Pant)

Male
25. Waist: __________ In.
26. Inseam: __________ In.

OR

Female
27. Size: __________
28. Length: ◯1 R ◯2 L

29. Satisfactory fit obtained? (Check or X)
- ◯ 1 YES
- ◯ 2 NO

C
(Twill Pant)

Male
30. Waist: __________ In.

OR

Female
31. Size: __________
32. Length: ◯1 R ◯2 L

33. Satisfactory fit obtained? (Check or X)
- ◯ 1 YES
- ◯ 2 NO

34. Notes and Comments:-

Appendix D: Utility Uniform Wear Test

Utility Uniform Wear Test

Thank you for participating in this wear test. The Navy Clothing and Textile Research Facility (NCTRF) is investigating a number of utility uniform designs. You have been chosen to evaluate two designs. Uniform A consists of a Poplin medium blue shirt with a twill navy blue trouser. Uniform B has a Chambray washed-blue shirt with denim trousers. Each uniform will be marked with the appropriate letter on the garment tags.

By taking part in this study your views, opinions, and preferences are important. You have the ability to influence the future design of the Navy's utility uniform. All of your comments will be treated in confidence and are greatly appreciated.

Instructions

Please wear both uniforms in place of your standard utility uniform. Launder the uniforms as necessary, but continually wear one or other of the uniforms. For example you start by wearing uniform B until it needs laundering. Switch to wearing uniform A. Then when uniform A needs laundering wear B.

This wear test will last approximately six months. The objective of the wear test is to compare the uniforms for: fit, design, suitability to your job, uniform functionality, durability, ease of care, and comfort. You will be visited by a team from NCTRF after about three and six months and will be asked to complete a survey each time. It is important to fill out these surveys as completely as possible, as this is where your views, opinions, and preferences will be collected.

If you have any questions please see your test monitor.

Utility Uniform
(User Survey)

1. Name: ______________________ 2. DOB: ____/____/____ (Day / Month / Year)

3. SSN: _ _ _ _ (Last Four Numbers) 4. Date: ____/____/____ (Day / Month / Year)

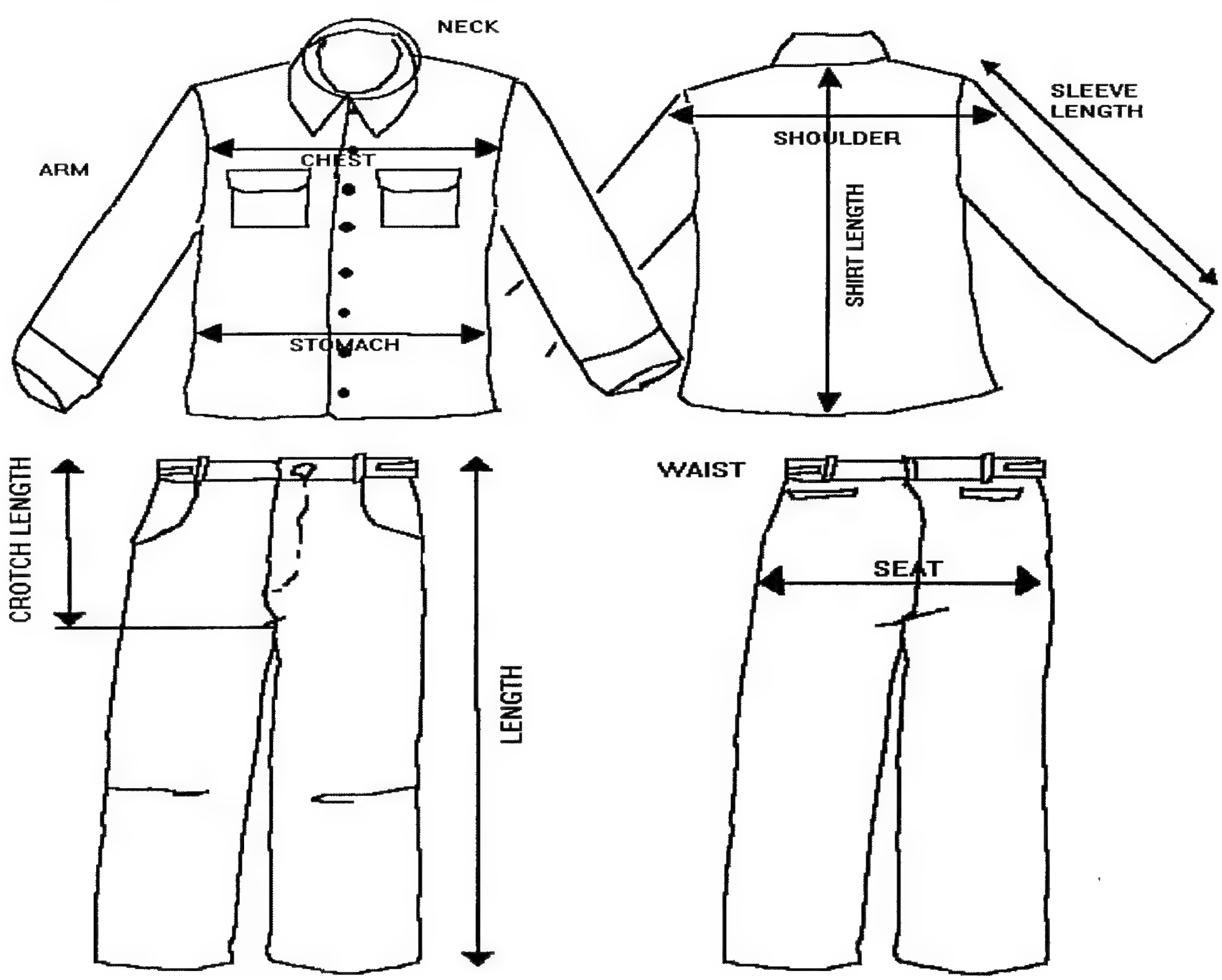
4s. Ship or Command: ____________________

Thank you for your participation in this study. Answer each question as fully and honestly as possible for each of the three uniforms (including the shirt and pants). Please provide comments where asked for. If a question does not have space, please reserve your comments until question 24.

For questions which give a number of choices as answers please **CHECK or FILL** the circle next to your response or responses. For example:

q30x. Are you currently on active duty? 29. ✓1 Yes ○2 No

For questions which ask about fit, please refer to the illustrations below.



Fit of Uniforms

q1a. Overall, do the following **SHIRTS** fit?

Shirt				If **NO** was the Shirt..				Please explain...
5a. **A/B**	◯ 1 Yes	◯ No	➪	◯ 2 Too Tight	◯ 3 Too Loose	◯ 4 Other	➪	6a. ______________
5c. **C**	◯ 1 Yes	◯ No	➪	◯ 2 Too Tight	◯ 3 Too Loose	◯ 4 Other	➪	6c. ______________

q1b. Overall, do the following **PANTS** fit?

Pant				If **NO** were the Pants..				Please explain...
7a. **A**	◯ 1 Yes	◯ No	➪	◯ 2 Too Tight	◯ 3 Too Loose	◯ 4 Other	➪	8a. ______________
7b. **B**	◯ 1 Yes	◯ No	➪	◯ 2 Too Tight	◯ 3 Too Loose	◯ 4 Other	➪	8b. ______________
7c. **C**	◯ 1 Yes	◯ No	➪	◯ 2 Too Tight	◯ 3 Too Loose	◯ 4 Other	➪	8c. ______________

Length

Scale:	Too Short	Just Right	Too Long
	1	**2**	**3**

q2a. For each **SHIRT** please **evaluate the length** for the areas listed, using the scale above.

	Shirt A/B 1	2	3	**Shirt C** 1	2	3
. Sleeve Length	a. ◯	◯	◯	c. ◯	◯	◯
10. Overall Length	a. ◯	◯	◯	c. ◯	◯	◯

q2b. For each pair of **PANTS** please **evaluate the length** for the areas listed, using the above scale.

	Pant A 1	2	3	**Pant B** 1	2	3	**Pant C** 1	2	3
11. Leg Length	a. ◯	◯	◯	b. ◯	◯	◯	c. ◯	◯	◯
12. Crotch Length	a. ◯	◯	◯	b. ◯	◯	◯	c. ◯	◯	◯

Describe the Fit

q3a. For each **SHIRT** please describe the **FIT** for the following areas:

	Shirt A/B Close Fitting	Regular Fit	Baggy Fit	**Shirt C** Close Fitting	Regular Fit	Baggy Fit
13. Overall Fit	a. ◯	◯	◯	c. ◯	◯	◯
14. Shoulders	a. ◯	◯	◯	c. ◯	◯	◯
15. Chest	a. ◯	◯	◯	c. ◯	◯	◯
6. Arms	a. ◯	◯	◯	c. ◯	◯	◯
7. Neck	a. ◯	◯	◯	c. ◯	◯	◯
18. Stomach	a. ◯	◯	◯	c. ◯	◯	◯

Describe the Fit (*Continued*)

q3b. For each pair of **PANTS** please describe the **FIT** for the following areas:

	Pant A			Pant B			Pant C		
	Close Fitting	Regular Fit	Baggy Fit	Close Fitting	Regular Fit	Baggy Fit	Close Fitting	Regular Fit	Baggy Fit
19. Overall Fit	a. ○	○	○	b. ○	○	○	c. ○	○	○
20. Waist	a. ○	○	○	b. ○	○	○	c. ○	○	○
21. Seat Area	a. ○	○	○	b. ○	○	○	c. ○	○	○
22. Thigh	a. ○	○	○	b. ○	○	○	c. ○	○	○

Rating of Fit

Scale:

Dislike Very Much	Dislike Moderately	Neither Like nor Dislike	Like Moderately	Like Very Much
1	**2**	**3**	**4**	**5**

q4a. For each **SHIRT** please rate how much you **like or dislike** the **FIT** for the areas listed, using the scale above.

	Shirt A/B					Shirt C				
	1	2	3	4	5	1	2	3	4	5
23. Overall Fit	a. ○	○	○	○	○	c. ○	○	○	○	○
24. Shoulders	a. ○	○	○	○	○	c. ○	○	○	○	○
25. Chest	a. ○	○	○	○	○	c. ○	○	○	○	○
26. Arms	a. ○	○	○	○	○	c. ○	○	○	○	○
27. Neck	a. ○	○	○	○	○	c. ○	○	○	○	○
28. Stomach	a. ○	○	○	○	○	c. ○	○	○	○	○

q4b. For each pair of **PANTS** please rate how much you **like or dislike** the fit for the areas listed, using the scale.

	Pant A					Pant B					Pant C				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
29. Overall Fit	a. ○	○	○	○	○	b. ○	○	○	○	○	c. ○	○	○	○	○
30. Waist	a. ○	○	○	○	○	b. ○	○	○	○	○	c. ○	○	○	○	○
31. Seat Area	a. ○	○	○	○	○	b. ○	○	○	○	○	c. ○	○	○	○	○
32. Thigh	a. ○	○	○	○	○	b. ○	○	○	○	○	c. ○	○	○	○	○

Design of Uniforms

q5a. Please rate how you **like or dislike** the **overall LOOK** of each **SHIRT**.

Shirt	Dislike Very Much	Dislike Moderately	Neither Like Nor Dislike	Like Moderately	Like Very Much	Please explain
A/B	○ 1	○ 2	○ 3	○ 4	○ 5 ⇨	34a. ______
33c. **C**	○ 1	○ 2	○ 3	○ 4	○ 5 ⇨	34c. ______

Design of Uniforms (*Continued*)

q5b. Please rate how you **like or dislike** the **overall LOOK** of each pair of **PANTS**

	Pant	Dislike Very Much	Dislike Moderately	Neither Like Nor Dislike	Like Moderately	Like Very Much		Please explain
35a.	A	○ 1	○ 2	○ 3	○ 4	○ 5 ⇨	36a.	______
35b.	B	○ 1	○ 2	○ 3	○ 4	○ 5 ⇨	36b.	______
35c.	C	○ 1	○ 2	○ 3	○ 4	○ 5 ⇨	36c.	______

q6. Please rate how you **like or dislike** the **DESIGN OF THE PANT LEGS** for each pair of **PANTS**

	Pant	Dislike Very Much	Dislike Moderately	Neither Like Nor Dislike	Like Moderately	Like Very Much		Please explain
37a.	A	○ 1	○ 2	○ 3	○ 4	○ 5 ⇨	38a.	______
37b.	B	○ 1	○ 2	○ 3	○ 4	○ 5 ⇨	38b.	______
37c.	C	○ 1	○ 2	○ 3	○ 4	○ 5 ⇨	38c.	______

q7. Are you able to **EASILY stencil or attach your name tag** to each pair of **PANTS?**

	Pant	YES	NO	If NO		Please explain the problem
39a.	A	○ 1	○ 2	⇨	40a.	______
39b.	B	○ 1	○ 2	⇨	40b.	______
39c.	C	○ 1	○ 2	⇨	40c.	______

Restriction in Activities

q8. Are you able to perform **ALL** of your daily activities while wearing the following garments?

				If NO were you restricted:				AND describe your activity.
	Shirt	YES	NO		A Little OR	A Lot		
41a.	A/B	○ 1	○	⇨	○ 3	○ 4	⇨	42a. ______
41c.	C	○ 1	○	⇨	○ 3	○ 4	⇨	42c. ______
	Pant							
43a.	A	○ 1	○	⇨	○ 3	○ 4	⇨	44a. ______
43b.	B	○ 1	○	⇨	○ 3	○ 4	⇨	44b. ______
43c.	C	○ 1	○	⇨	○ 3	○ 4	⇨	44c. ______

Suitability

q9. Are the following garments **suited** for **your** particular Job?

	Shirt	YES	NO		If NO please describe what needs to be changed to make it ideal for your specific job.
45a.	A/B	○ 1	○ 2	⇨	46a. ______
45c.	C	○ 1	○ 2	⇨	46c. ______
	Pant				
47a.	A	○ 1	○ 2	⇨	48a. ______
47b.	B	○ 1	○ 2	⇨	48b. ______
47c.	C	○ 1	○ 2	⇨	48c. ______

Pockets

q For each garment, please rate how **easy or difficult** the pockets are to use for your regular duties?

Shirt	Very Difficult	Fairly Difficult	Acceptable	Fairly Easy	Very Easy		Please Explain
49a. **A/B**	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5	➪	50a. ____________
49c. **C**	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5	➪	50c. ____________
Pant (Front Pockets)							
51a. **A**	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5	➪	52a. ____________
51b. **B**	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5	➪	52b. ____________
51c. **C**	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5	➪	52c. ____________
Pant (Rear Pockets)							
51ar. **A**	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5	➪	52ar. ____________
51br. **B**	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5	➪	52br. ____________
51cr. **C**	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5	➪	52cr. ____________

q11. If the pockets were **not acceptable or difficult** to use please check **ALL the reasons** why they were this way.

Shirt	Too Big	Too Small	Too High	Too Low	Too Deep	Too Shallow	Too Tight	Too Loose	Wrong Angle	Wrong Location
. **A/B**	◯1	◯2	◯3	◯4	◯5	◯6	◯7	◯8	◯9	◯10
53c. **C**	◯1	◯2	◯3	◯4	◯5	◯6	◯7	◯8	◯9	◯10
Pant (Front Pockets)										
54a. **A**	◯1	◯2	◯3	◯4	◯5	◯6	◯7	◯8	◯9	◯10
54b. **B**	◯1	◯2	◯3	◯4	◯5	◯6	◯7	◯8	◯9	◯10
54c. **C**	◯1	◯2	◯3	◯4	◯5	◯6	◯7	◯8	◯9	◯10
Pant (Rear Pockets)										
54ar. **A**	◯1	◯2	◯3	◯4	◯5	◯6	◯7	◯8	◯9	◯10
54br. **B**	◯1	◯2	◯3	◯4	◯5	◯6	◯7	◯8	◯9	◯10
54cr. **C**	◯1	◯2	◯3	◯4	◯5	◯6	◯7	◯8	◯9	◯10

Durability

q Please indicate **all the types of durability problems** you have found with each SHIRT and pair of PANTS.

Shirt	Shrinks	Stains	Fades	Rips/ Tears	Seams Fail	Fasteners Fail	Buttons Fail	Abrasions	Other	If **OTHER** describe problem.
55a. **A/B**	○1	○2	○3	○4	○5	○6	○7	○8	○9 ⇨	56a. ______
55b. **C**	○1	○2	○3	○4	○5	○6	○7	○8	○9 ⇨	56c. ______
Pant										
57a. **A**	○1	○2	○3	○4	○5	○6	○7	○8	○9 ⇨	58a. ______
57b. **B**	○1	○2	○3	○4	○5	○6	○7	○8	○9 ⇨	58b. ______
57c. **C**	○1	○2	○3	○4	○5	○6	○7	○8	○9 ⇨	58c. ______

q13. For the following garments please indicate **all areas** that have any durability problems.

Shirt	Arms	Back	Chest	Collar	Front	Cuff	Pockets	Seams	Buttons
59a. **A/B**	○1	○2	○3	○4	○5	○6	○7	○8	○9
59b. **C**	○1	○2	○3	○4	○5	○6	○7	○8	○9

Pant	Legs	Knee	Front	Seat	Waist	Pockets	Seams	Zippers	Buttons/ Snaps	Crotch
60a. **A**	○1	○2	○3	○4	○5	○6	○7	○8	○9	○10
60b. **B**	○1	○2	○3	○4	○5	○6	○7	○8	○9	○10
60c. **C**	○1	○2	○3	○4	○5	○6	○7	○8	○9	○10

q14. Overall please rate how durable or not durable each garment is.

Shirt	Not Durable	Fairly Durable	Durable	Very Durable		Please explain
61a. **A/B**	○ 1	○ 2	○ 3	○ 4	⇨	62a. ______
61c. **C**	○ 1	○ 2	○ 3	○ 4	⇨	62c. ______
Pant						
63a. **A**	○ 1	○ 2	○ 3	○ 4	⇨	64a. ______
63b. **B**	○ 1	○ 2	○ 3	○ 4	⇨	64b. ______
63c. **C**	○ 1	○ 2	○ 3	○ 4	⇨	64c. ______

Frequency of Wear

q1 Have you been wearing the uniforms since the **beginning of the test period until this point**?

Uniform			If **NO** -	How many weeks have you worn them?
65a. **A**	○1 Yes	○2 No	⇨	66a. ________ Weeks
65b. **B**	○1 Yes	○2 No	⇨	66b. ________ Weeks
65b. **C**	○1 Yes	○2 No	⇨	66c. ________ Weeks

q16. How many **days** do you wear **each** uniform **per week**?

67a. Uniform **A** _____ Days   67b. Uniform **B** _____ Days   67c. Uniform **C** _____ Days

Ease of Care

q17. Please rate **how well or how poorly** each garment **maintains its appearance after laundering**.

Shirt	Very Poorly	Poorly	OK	Well	Very Well
68a. **A/B**	○ 1	○ 2	○ 3	○ 4	○ 5
68c. **C**	○ 1	○ 2	○ 3	○ 4	○ 5
Pant					
69a. **A**	○ 1	○ 2	○ 3	○ 4	○ 5
69b. **B**	○ 1	○ 2	○ 3	○ 4	○ 5
69c. **C**	○ 1	○ 2	○ 3	○ 4	○ 5

q18. Please **estimate** the proportion of the time your garments are/were shipboard laundered.

	Always	Three Quarters	Two Thirds	Half the Time	One Third	One Quarter	Never	Other
70.	○1 100%	○2 75%	○3 66%	○4 50%	○4 33%	○5 25%	○6 0%	○7 __

q19. How often do you launder each uniform?

71a. Uniform **A:** Every _____ Days   71b Uniform **B:** Every _____ Days   71c. Uniform **C:** Every _____ Days

Scale:				
Very Uncomfortable	Uncomfortable	Acceptable	Comfortable	Very Comfortable
1	2	3	4	5

Comfort

q20a. For the following conditions please rate how **comfortable or uncomfortable** each **SHIRT** is to wear.

		Shirt A/B						Shirt C				
		1	2	3	4	5		1	2	3	4	5
72. In Hot Conditions	a.	◯	◯	◯	◯	◯	c.	◯	◯	◯	◯	◯
73. In Cold Conditions	a.	◯	◯	◯	◯	◯	c.	◯	◯	◯	◯	◯
74. Overall	a.	◯	◯	◯	◯	◯	c.	◯	◯	◯	◯	◯

q20b. For the following conditions please rate how **comfortable or uncomfortable** each pair of **PANTS** is to wear.

		Pant A						Pant B						Pant C				
		1	2	3	4	5		1	2	3	4	5		1	2	3	4	5
75. In Hot Conditions	a.	◯	◯	◯	◯	◯	b.	◯	◯	◯	◯	◯	c.	◯	◯	◯	◯	◯
76. In Cold Conditions	a.	◯	◯	◯	◯	◯	b.	◯	◯	◯	◯	◯	c.	◯	◯	◯	◯	◯
77. Overall	a.	◯	◯	◯	◯	◯	b.	◯	◯	◯	◯	◯	c.	◯	◯	◯	◯	◯

Overall

q Please give an **overall** rating for each garment.

Shirt	Very Poor	Poor	Fair	Good	Very Good
78a. **A/B**	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5
78c. **C**	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5
Pant					
79a. **A**	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5
79b. **B**	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5
79c. **C**	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5

q22. Would you like to see the current "Bell Bottoms" retained on any new Utility Uniform?

80. ◯1 Yes ◯2 No 81. Please explain your answer: ____________________

q23. Would you like to see a prescribed method of rolling up shirt sleeves?

82. ◯1 Yes ◯2 No 83. Please explain your answer: ____________________

q24. Please provide any further comments you may have about the uniforms you have been wearing. If you need extra space please use the back of this survey.

____

____

____

____________________ **Please turn over to complete the comparison section...☞**

Comparison

q25a. For each of the following categories please rank the two **SHIRTS** in order of preference. (**1**= Most Favored to **2**= Least Favored. If you like the shirts the **same**, give them an **equal rating**)

	Shirt **A/B**	Shirt **C**
85. Fit of Shirt	Rank:	Rank:
86. Comfort of Shirt	Rank:	Rank:
87. Durability of Shirt	Rank:	Rank:
88. Appearance of Shirt	Rank:	Rank:

(1 = Most Favored, 2 = Least Favored)

q25b. For each of the following categories please rank the three pairs of **PANTS** in order of preference. (**1**= Most Favored to **3**= Least Favored. If you like the pants the **same** give them an **equal rating**.)

	Pants **A**	Pants **B**	Pants **C**
89. Fit of Pants	Rank:	Rank:	Rank:
90. Comfort of Pants	Rank:	Rank:	Rank:
91. Durability of Pants	Rank:	Rank:	Rank:
92. Appearance of Pants	Rank:	Rank:	Rank:

(1 = Most Favored Pant, 2 = second Most Favored, 3 = Least Favored)

Comparison to Dungarees

Scale:

Like **Current** Much Less	Like **Current** Less	Like **Current** Same	Like **Current** More	Like **Current** Much More
1	**2**	**3**	**4**	**5**

q26a. For the following categories please compare **the SHIRT you like the most** (A/B or C) to the **CURRENT utility uniform** (Dungaree Uniform), using the scale above.

93. Fit of Shirt	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5
94. Comfort of Shirt	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5
95. Durability of Shirt	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5
96. Appearance of Shirt	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5

q26b. For the following categories please compare **the pair of PANTS you like the most** (A, B or C) to the **CURRENT utility uniform** (Dungaree Uniform), using the scale above.

97. Fit of Pants	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5
98. Comfort of Pants	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5
99. Durability of Pants	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5
100. Appearance of Pants	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5

Thank you for your help and participation

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U.S. Navy Wear Test and User Evaluation of Oxford Shoes

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Executive Summary

The U.S. Navy Clothing and Textile Research Facility (NCTRF) tested three new Oxford shoes to determine their suitability as replacements for the current *Oxford Shoe*. The study was conducted in three, eight-week phases, one for each of the three different shoe types (Phase I = Direct Attachment, Phase II = Welt/Cement and Phase III = True Welt). All three Oxford Shoes were similar in appearance with a black leather upper and black sole. All shoes were manufactured by *Bates Corporation*; type of shoe and pricing for each shoe is as follows:

Direct Attachment shoe: Men's $36.00, Women's $35.00
Welt/Cement shoe: Men's $40.50, Women's $39.50
True Welt shoe: Men's $32.50, Women's $31.50

Data were collected after each phase via a comprehensive questionnaire that assessed *fit, wear time, comfort, performance, and durability*. Statistical analyses were conducted to determine the respondents' favorite shoe based on the above mentioned characteristics. All three shoes were rated in a positive manner; however, the Direct Attachment and True Welt shoes were preferred over the Welt/Cement in most all categories.

The recommendation for shoe purchase, based on the survey results is as follows:

Best Choices = Direct Attachment or True Welt shoe
Adequate Choice = Welt/Cement

Introduction

The following is a report of the *Navy Oxford Shoe Study*. This study was conducted to give both men and women an opportunity to evaluate candidate replacement shoes for the current *Oxford shoe*. Currently, the appearance of the women's shoe is slightly different from the men's shoe, in that there is a small section of top stitching on the leather upper. All three new candidates were similar in appearance with a plain black leather upper and black sole. The three shoes that were used in the study were all manufactured by *Bates Corporation* and tested at three different U.S. Navy installations to determine user preference ratings.

Methods/Materials

The Oxford Shoe Study was conducted in three, eight-week phases - one phase for each shoe (each phase consisted of participants wearing one candidate Oxford shoe). The schedule of wear was as follows: Phase I = Direct Attachment, Phase II = Welt/Cement and Phase III = True Welt. Approximately 300 male and female subjects were issued shoes for all three phases (eight-week period). The exterior appearance of all three shoes was almost exactly the same, with the method of sole attachment, and slight variations in the tread pattern being the only difference in the shoes. After each eight-week phase, participants filled out a user survey to assess the *fit of the shoe, wear time, comfort, performance, and durability.* The initial intent of the study was to analyze the data in a within-subjects manner. That is, the analyses would take into account that every test participant participated in all three phases. However, due to the inadequate number of subjects completing all three phases of the study, between-subjects' analyses were used. A between-subjects' analysis assumes independence in all three phases and does not assume test participants completed all three phases. This does not compromise the findings of this study, as each individual participant's responses did not contribute more to one phase than any other. In addition, using between-subjects' analyses allowed a larger sample size to be used, increasing the power of the test; rather than the inadequate number (n=31) of subjects that completed the survey for all three phases for within-subjects' analyses.

Results

Four hundred and seventy-seven surveys were tabulated for the final analyses:

	Overall	Male	Female	No issue sheet
Direct Attachment	132	62	52	18
Welt/Cement	164	75	67	22
True Welt	181	72	77	32
Total	477	209	196	72

For those test participants who did not have issue sheets, the data were excluded as there was no way to categorize the respondents as male or female for the analyses performed. Thus, for all analyses performed, a maximum of 405 subjects were included. The number of subjects varied for each question analyzed, as participants did not always answer every question. The exclusion of these subjects did not affect the integrity of the analyses given the relatively large sample size. Based on the original 310 issue sheets that were distributed for completion at the beginning of the first phase; overall, approximately 44% of test participants responded in the three different phases (those who had issue sheets). Direct Attachment had a 37% completion rate, Welt/Cement had a 46% completion rate and True Welt had a 48% completion rate. In general, these are good response rates for survey research. The relatively high completion rate is due in part to the use of a between-subjects' analyses. Had a within-subjects' analyses been used, only 10% of respondents' ratings would have been analyzed. In similar kinds of survey methodology, it is common to only receive completed surveys for 20-30% of respondents.

For the Direct Attachment shoe, 95.2% of male respondents and 82.7% of female respondents surveyed, said their shoes fit and 91.9% of males and 86.0% of females felt they were issued the correct size. For the Welt/Cement shoe, 85.3% of male and 74.2% of female respondents felt their shoes fit and 92.0% of males and 78.8% of females felt they were issued the correct size. For the True Welt shoe, 98.6% of males and 75.3% of females felt their shoes fit and 95.8% of males and 87.0% of females said they were issued the correct size. For those test participants who reported that their shoes did not fit (both male and female), most said the shoes were "too tight." Females reported more problems with fit than did males. Again, in most cases,

the main complaint was the shoes were "too tight." For the Direct Attachment shoe, 17.3% of females reported the shoe "too tight"; for the Welt/Cement, 24.2% reported the shoe "too tight" and 1.5% as "too loose" and for the True Welt, 16.9% reported the shoe as "too tight" and 7.8% as "too loose." The males who reported that the shoes did not fit, rated the shoes as "too tight" in all three phases. For males, there was a statistically significant difference for fit of the shoe at a 95% confidence level (X^2=10.45, df=2, p<0.005). Males rated the True Welt shoe as having a significantly better fit than the Welt/Cement shoe. However, there was no difference in fit between the Direct Attachment and True Welt shoes. No differences were present for women. No statistical differences were present among the three phases for men or women on whether respondents felt they were issued the correct size of shoe.

In general, all three shoes were rated in a positive manner; however, the Phase I, Direct Attachment shoe, and the Phase III, True Welt, were favored over the Phase II, Welt/Cement in most cases. Unless otherwise stated, for all scaled questions, a two-way between-subjects' Analysis of Variance (ANOVA) was used for each dependent variable with gender and shoe type serving as the between-subjects' factors. If there was a statistically significant difference for shoe type at a 95% confidence level, a Student-Newman-Keuls Post Hoc Test was used to determine which of the three shoe types was significantly different from the other(s). The results that follow are summarized by *fit, wear time, comfort, performance, and durability*.

Fit

Collapsing across all three shoe types, there was a statistically significant difference for Gender at a 95% Confidence Level for the toes ($F=7.96(1,359)$, $p<0.005$), heel ($F=10.11(1,360)$, $p<0.002$) and top of foot ($F=4.80(1,360)$, $p<0.029$) portions of the Oxford Shoe (see Tables 1 and 2). Males rated all three shoes a better fit for the toes and top of the foot, while females rated all three shoes looser than males in the heel area. The Arch fit was statistically different between the Direct Attachment and Welt/Cement shoe types at a 95% Confidence Level ($F=3.18(2,357)$, $p<0.043$) but not between the Direct Attachment and True Welt (see Tables 1 and 2). The Direct Attachment and True Welt shoes received the closest rating to 3.0 or a "just right" fit. There were no statistically significant differences for overall fit among the three types of shoes. The results for fit indicate some statistically significant differences; however, in all cases the resulting differences were small and not considered practically informative. In most cases, the differences that were found were less than one-quarter of a scale point.

- *Question (#4): Please rate the fit for the shoes for the following areas, stating whether it is acceptable or unacceptable.*

Scale: Tight	Slightly Tight	Just Right	Slightly Loose	Loose
1	2	3	4	5

TABLE 1:

Shoe Type	Direct Attachment		Welt/Cement		True Welt	
	Male	Female	Male	Female	Male	Female
Shoe Area						
Toes	64.8%	58.3%	75.7%	52.5%	78.1%	60.3%
Heel	92.6%	81.6%	84.3%	69.4%	88.9%	67.6%
Arch	79.6%	93.9%	81.2%	78.3%	85.9%	83.6%
Top of Foot	68.5%	63.3%	68.6%	55.7%	81.5%	65.7%
Ball of Foot	90.7%	85.7%	82.9%	85.0%	90.6%	83.6%
Overall	84.9%	75.0%	78.3%	54.8%	90.5%	69.2%
(% of respondents who answered "just right")						

Fit (continued)

TABLE 2:

Shoe Type	Direct Attachment			Welt/Cement			True Welt		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Shoe Area									
Toes [1]	2.81	2.65	2.74	2.76	2.43	2.60	2.80	2.62	2.70
Heel [1]	2.98	3.20	3.09	3.01	3.23	3.11	3.02	3.21	3.11
Arch [2]	3.09	3.02	3.06	2.88	2.88	2.88	2.97	2.88	2.92
Top of Foot [1]	2.81	2.61	2.72	2.71	2.57	2.65	2.85	2.69	2.77
Ball of Foot	2.94	2.90	2.92	2.83	2.90	2.86	2.95	2.88	2.92
Overall	2.94	2.77	2.87	2.78	2.68	2.73	2.89	2.83	2.86
(mean responses)									

1 = Statistically significant difference at a 95% Confidence Level for Gender
2 = Statistically significant difference at a 95% Confidence Level for Shoe Type

All three shoes were rated in a positive manner; males liked all three shoes better than did their female counterparts (see Table 3). The ratings for the Direct Attachment and True Welt shoes were similar between both the males and females. The males rated the two shoes better than "like moderately", while the females rated the two shoes between "neutral" and "like moderately." There was no statistical difference among the three shoe types.

- *Question (#5): Please rate how much you like or dislike the overall fit of the shoes.*

Scale: Dislike Very Much	Dislike Moderately	Neutral	Like Moderately	Like Very Much
1	2	3	4	5

TABLE 3:

Shoe Type	Direct Attachment		Welt/Cement		True Welt	
	Male	Female	Male	Female	Male	Female
Like/Dislike	93.6%	74.9%	81.3%	65.1%	93.6%	79.3%
Mean	4.21	3.48	3.84	3.21	4.08	3.42
(% of respondents who answered "neutral", "like moderately" and "like very much")						

Wear Time

The number of weeks the shoes were worn varied between 4.97 and 6.18 for the males and between 4.12 and 5.37 weeks for the females. The Direct Attachment shoe was worn the longest in both cases (see Table 4). Respondents also wore the Direct Attachment shoe more often during the week.

- *Question (#6): Please estimate how many weeks during this test period you wore the dress shoes.*

- *Question (#7): Please estimate, on average, how often or how many times you wore these shoes in a week.*

TABLE 4:

Shoe Type	Direct Attachment		Welt/Cement		True Welt	
	Male	Female	Male	Female	Male	Female
Wear Time						
# of Weeks	6.18	5.37	4.97	4.12	5.21	4.22
Times per Week	4.63	4.27	3.95	3.61	4.03	3.07

Comfort

Collapsing across all three shoe types, there was a statistically significant difference for Gender at a 95% Confidence level for the overall comfort ($F=24.25(1,398)$ $p<0.000$) and shoe inserts ($F=8.49$ $(1,394)$ $p<0.004$). The results for overall comfort indicate the men rated all three shoes more comfortable than did women (see Tables 5 and 6). Shoe type results were also significant at a 95% Confidence level for the comfort of the arch supports ($F=3.82(2,397)$ $p<0.023$) where the Direct Attachment shoe was significantly different from the Welt/Cement but not the True Welt shoe (see Tables 5 and 6). There was a borderline significance for comfort of the sole insert where the Direct Attachment shoe was preferred to the Welt/Cement and the True Welt. The Arch Support of the Direct Attachment shoe was significantly more comfortable than the Welt/Cement shoe but not the True Welt shoe.

Comfort (continued)

- *Question (#10): Please indicate the overall comfort of the shoes.*
- *Question (#12): Please indicate the comfort level of the arch supports.*
- *Question (#13): Please indicate the comfort level of the shoe inserts.*

Scale:				
Very Comfortable	Comfortable	OK	Uncomfortable but Bearable	Uncomfortable Could not Wear for Long
1	2	3	4	5

TABLE 5:

Shoe Type	Direct Attachment		Welt/Cement		True Welt	
	Male	Female	Male	Female	Male	Female
Comfort						
Overall	91.9%	75.0%	79.9%	64.2%	94.4%	78.9%
Arch Support	88.5%	96.2%	86.6%	85.1%	91.7%	85.5%
Shoe Insert	98.4%	92.1%	94.7%	90.8%	98.6%	88.2%
(% of respondents who answered "ok", "comfortable" and "very comfortable")						

TABLE 6:

Shoe Type	Direct Attachment			Welt/Cement			True Welt		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Comfort									
Overall [1]	2.00	2.58	2.26	2.33	2.87	2.58	2.01	2.63	2.33
Arch Support [2]	2.18	2.13	2.16	2.44	2.55	2.49	2.26	2.50	2.39
Shoe Insert [1]	1.90	2.16	2.02	2.21	2.37	2.29	2.04	2.45	2.25
(mean responses)									

1 = Statistically significant difference at a 95% Confidence Level for Gender
2 = Statistically significant difference at a 95% Confidence Level for Shoe Type

*Please note the direction of the scale for Questions 10,12, and 13. A smaller mean value indicates greater comfort.

Comfort (continued)

Collapsing across all three shoe types, there was a statistically significant effect for Gender at a 95% Confidence Level for comfort in hot ($F=14.91(1,388)$, $p<0.000$), cold ($F=7.07(1,358)$ $p<0.008$), standing ($F=15.90(1,398)$ $p<0.000$), walking ($F=22.48(1,394)$ $p<0.000$), marching ($F=14.73(1,321)$ $p<0.000$), running ($F=4.20(1,309)$ $p<0.041$), ascending ladder ($F=16.33(1,389)$ $p<0.000$) and descending ladder ($F=15.35(1,389)$ $p<0.000$) conditions. Further, there was a statistically significant difference among the shoe types for ascending ($F=3.29(2,389)$ $p<0.038$) and descending ($F=3.54(2,389)$ $p<0.030$) ladders (see Tables 7 and 8). The Direct Attachment shoe was significantly more comfortable than the Welt/Cement for ascending ladders and significantly more comfortable than both the Welt/Cement and True Welt for descending ladders. In all comfort conditions, males rated the shoes significantly more comfortable than their female counterparts. Again, though statistically significant most differences that were detected were relatively small and not practically informative. The larger differences between men and women were apparent in the walking and marching comfort ratings with approximately a half-point scale difference.

- *Question (#16): For the following conditions please indicate how Comfortable or Uncomfortable the shoes were.*

Scale:

Very Comfortable	Comfortable	OK	Uncomfortable but Bearable	Uncomfortable Could not Wear for Long
1	2	3	4	5

Comfort (continued)

TABLE 7:

Shoe Type	Direct Attachment		Welt/Cement		True Welt	
	Male	Female	Male	Female	Male	Female
Comfort						
Hot	90.0%	81.6%	89.4%	81.8%	91.6%	83.5%
Cold	93.3%	92.0%	92.0%	83.3%	95.6%	85.7%
Standing	91.9%	80.8%	86.4%	73.2%	90.3%	78.0%
Walking	87.1%	71.2%	86.3%	67.2%	91.4%	77.7%
Marching	84.3%	73.7%	83.3%	68.0%	92.0%	78.0%
Running	80.9%	78.0%	76.3%	62.5%	86.2%	79.0%
Ascending Ladders	93.5%	80.0%	80.6%	75.7%	94.3%	80.0%
Descending Ladders	93.5%	82.0%	81.9%	77.2%	95.7%	80.0%
(% of respondents who answered "ok", "comfortable" and "very comfortable")						

TABLE 8:

Shoe Type	Direct Attachment			Welt/Cement			True Welt		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Comfort									
Hot [1]	2.35	2.76	2.53	2.39	2.76	2.56	2.39	2.75	2.58
Cold [1]	2.22	2.58	2.38	2.65	2.70	2.67	2.35	2.71	2.54
Standing [1]	2.03	2.50	2.25	2.36	2.69	2.52	2.29	2.77	2.54
Walking [1]	2.08	2.63	2.33	2.33	2.84	2.57	2.24	2.79	2.53
Marching [1]	2.24	2.68	2.43	2.62	2.98	2.78	2.35	2.93	2.63
Running [1]	2.57	2.68	2.63	2.80	3.13	2.94	2.57	2.90	2.74
Ascending [1,2]	2.16	2.56	2.34	2.54	2.86	2.70	2.29	2.85	2.58
Descending [1,2]	2.16	2.54	2.33	2.54	2.85	2.69	2.31	2.85	2.59
(mean responses)									

1 = Statistically significant difference at a 95% Confidence Level for Gender
2 = Statistically significant difference at a 95% Confidence Level for Shoe Type

*Please note the direction of the scale for Question 16. A <u>smaller</u> mean value indicates <u>greater</u> comfort.

Comfort (continued)

A Chi-Square analysis revealed no statistical difference for arch support among the three shoe types for males or females. For those respondents who did not answer "just right" most males and females rated the arch support as "too low."

- *Question (#11): Please rate the shoe's arch support.*

Scale:		
Too Low	Just Right	Too High
1	2	3

TABLE 9:

Shoe Type	Direct Attachment		Welt/Cement		True Welt	
	Male	Female	Male	Female	Male	Female
Comfort Arch Support	83.9%	96.0%	74.3%	81.5%	80.9%	87.8%
(% of respondents who answered "just right")						

A Chi-Square analysis revealed no statistical difference among the three shoe types for males or females. In general, extra cushioning or socks was not needed with the shoes (see Table 10). This reflects earlier fit data where most respondents, who had a problem with fit, rated the shoes as "too tight."

- *Question (#14): Did you need to use any additional inserts or cushioning with the shoes?*
- *Question (#15): Did you need to use more than one pair of socks with the shoes?*

Scale:	
Yes	No
1	2

Comfort (continued)

TABLE 10:

Shoe Type	Direct Attachment		Welt/Cement		True Welt	
	Male	Female	Male	Female	Male	Female
Comfort						
Additional Cushioning	96.8%	98.1%	90.7%	97.0%	97.2%	96.1%
More Socks	91.8%	96.1%	90.7%	95.4%	91.7%	90.9%
(% of respondents who answered "no")						

Chi-Square analyses revealed no significant differences between males or females among the three shoe types for any of the problem criteria except for the "other" category. There was a significant difference (X^2=10.72, df=2, p<0.005) for males among the three shoe phases for the "other" category (see Table 11). A Fisher's Exact test revealed that the males reported significantly more problems at a 95% Confidence Level for the Welt/Cement shoe than the True Welt shoe (p<0.001). The significance for the "other" category is a statistical artifact resulting from the way participants answered the question. Many participants simply wrote "none" or "no" in the blank provided, resulting in the larger number of responses reported for the "other" category for the Welt/Cement shoe.

- *Question (#18): Did the shoes cause any of the following problem?*

TABLE 11:

Shoe Type	Direct Attachment		Welt/Cement		True Welt	
	Male	Female	Male	Female	Male	Female
Problems						
Aching Back	1	1	0	2	3	2
Aching Feet	4	13	7	12	3	14
Aching Legs	1	0	1	2	1	2
Blisters	2	1	1	10	0	8
Callouses	4	1	3	4	1	4
Foot Cramps	1	3	2	6	2	5
Other	7	4	15	10	2	5
(Number of respondents who reported problems)						

Comfort (continued)

Overall, the comfort level of all three shoes was rated positively. All mean responses were between 2.0 and 3.0, or "comfortable" and "ok", respectively on the survey scale with the exception of the running category (rated 3.13) for females wearing the Welt/Cement shoe.

Performance

Statistically significant differences in traction were found for the different shoe types at a 95% Confidence Level for oil covered ($F=3.73(2,289)$ $p<0.025$), wet/moist ($F=4.51(2,381)$ $p<0.012$), non-skid ($F=3.53(2,370)$ $p<0.030$), painted ($F=5.38(2,351)$ $p<0.005$) and ladder ($F=4.50(2,372)$ $p<0.012$) conditions (see Tables 12 and 13). The Direct Attachment shoe was significantly better than the Welt/Cement but not better than the True Welt for the ladder and smooth steel conditions. The Direct Attachment shoe had significantly better traction than the True Welt Shoe but not the Welt/Cement for oil covered, carpet, pavement and mud conditions. Finally, the Direct Attachment shoe had significantly better traction than both the Welt/Cement and True Welt in wet/moist and painted conditions. A statistically significant gender difference was also present for traction on ladders ($F=6.16(1,372)$ $p<0.014$). Males rated the shoes as having better traction than females in the ladder condition (see Tables 12 and 13). Again, though the Direct Attachment shoe was preferred slightly, in most cases, the difference is only approximately a quarter of a scale point, indicating these differences are not very large. In all cases, the mean responses for all shoes were between "fair" and "good."

Performance (continued)

- *Question (#20): Please rate the shoe's traction on the following surfaces.*

Scale:		
Poor	Fair	Good
1	2	3

TABLE 12:

Shoe Type	Direct Attachment		Welt/Cement		True Welt	
	Male	Female	Male	Female	Male	Female
Traction						
Waxed	98.3%	97.9%	95.9%	96.9%	95.9%	97.3%
Oil Covered	100.0%	96.6%	86.4%	89.8%	83.1%	91.1%
Wet/Moist	96.6%	100.0%	93.1%	95.1%	90.1%	93.1%
Non-Skid	100.0%	100.0%	94.4%	98.4%	97.3%	98.6%
Painted	100.0%	100.0%	98.5%	98.3%	96.8%	95.5%
Wooden	98.1%	100.0%	98.4%	100.0%	96.7%	96.9%
Ladders	98.4%	95.7%	88.4%	88.5%	91.4%	91.6%
Smooth Steel	93.9%	97.5%	94.0%	96.4%	95.7%	98.5%
Carpet	100.0%	100.0%	98.7%	98.3%	97.0%	98.6%
Pavement	100.0%	100.0%	98.6%	98.5%	95.6%	98.7%
Mud	93.0%	100.0%	95.0%	100.0%	87.3%	94.9%
Grass	94.1%	100.0%	93.6%	100.0%	93.6%	96.9%
(% of respondents who answered "fair" and "good")						

Performance (continued)

TABLE 13:

Shoe Type	Direct Attachment			Welt/Cement			True Welt		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Traction									
Waxed	2.79	2.69	2.75	2.66	2.56	2.61	2.61	2.62	2.61
Oil Covered [2]	2.55	2.60	2.57	2.39	2.31	2.35	2.29	2.34	2.31
Wet/Moist [2]	2.65	2.73	2.69	2.55	2.50	2.53	2.45	2.49	2.47
Non-Skid [2]	2.92	2.83	2.88	2.79	2.65	2.72	2.78	2.76	2.77
Painted [2]	2.88	2.79	2.83	2.70	2.63	2.67	2.67	2.58	2.62
Wooden	2.84	2.79	2.82	2.75	2.64	2.70	2.73	2.65	2.69
Ladders [1,2]	2.82	2.63	2.74	2.57	2.39	2.48	2.66	2.54	2.60
Smooth Steel	2.73	2.68	2.71	2.61	2.44	2.53	2.68	2.59	2.64
Carpet	2.91	2.85	2.88	2.86	2.72	2.80	2.77	2.74	2.76
Pavement	2.90	2.86	2.88	2.86	2.71	2.79	2.78	2.72	2.75
Mud	2.60	2.82	2.71	2.58	2.58	2.58	2.55	2.47	2.51
Grass	2.73	2.76	2.74	2.65	2.60	2.62	2.63	2.59	2.61
(mean responses)									

1 = Statistically significant difference at a 95% Confidence Level for Gender

2 = Statistically significant difference at a 95% Confidence Level for Shoe Type

Durability

A Chi-Square analysis indicated there were no significant durability differences at a 95% Confidence Level among the three shoe types for males or females (see Table 14). Most damage that was reported consisted of scuffs and scratches to the upper leather portion of the shoes, which are reflective of normal wear and tear.

Durability (continued)

- *Question (#21): Did your shoes get damaged in any way? (Rips, Tears, Scratches in Leather, Seams Separate, etc.)*

Scale:	
Yes	No

TABLE 14:

Shoe Type	Direct Attachment		Welt/Cement		True Welt	
	Male	Female	Male	Female	Male	Female
Durability Shoes Damaged	84.7%	84.0%	96.0%	84.8%	88.7%	90.8%
(% of respondents who answered "no")						

There were no significant differences at a 95% confidence level among the three shoe types for ease of maintaining a military shine. All mean responses reflect that the shoes were "ok" to "fairly easy" to shine (see Tables 15 and 16).

- *Question (#22): Please rate how easy or difficult it is to maintain a professional military shine to these shoes.*

Scale:				
Very Difficult	Fairly Difficult	OK	Fairly Easy	Very Easy
1	2	3	4	5

TABLE 15:

Shoe Type	Direct Attachment		Welt/Cement		True Welt	
	Male	Female	Male	Female	Male	Female
Military Shine	85.5%	92.0%	92.0%	92.5%	94.4%	94.6%
(% of respondents who answered "ok", "fairly easy" and "very easy")						

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Durability (continued)

TABLE 16:

Shoe Type	Direct Attachment			Welt/Cement			True Welt		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Military Shine	3.61	3.68	3.64	3.63	3.66	3.64	3.94	3.69	3.81
(mean responses)									

Overall

Collapsing across all three shoe types, there was a statistically significant difference for Gender at a 95% confidence level for the look of the shoe ($F=4.16(1,396)$, $p<0.042$). Males rated the look of the shoes more positively than the females in the Welt/Cement and True Welt conditions (see Tables 17 and 18). There was not a statistical difference at a 95% confidence level among the different shoe types for look of the shoes.

- *Question (#23): Please rate the look of the shoes.*

Scale:

Dislike Very Much	Dislike Moderately	Neither Like Nor Dislike	Like Moderately	Like Very Much
1	2	3	4	5

TABLE 17:

Shoe Type	Direct Attachment		Welt/Cement		True Welt	
	Male	Female	Male	Female	Male	Female
Look of Shoe	96.8%	98.0%	98.6%	88.0%	97.2%	93.5%
(% of respondents who answered "neither like nor dislike", "like moderately" and "like very much")						

Overall (continued)

TABLE 18:

Shoe Type	Direct Attachment			Welt/Cement			True Welt		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Look of Shoe [1]	4.21	4.22	4.21	4.18	3.90	4.04	4.20	3.92	4.05
(mean responses)									

1 = Statistically significant difference at a 95% Confidence Level for Gender

Males rated the shoes significantly more positive than their female counterparts for the overall rating of all three shoes (see Tables 19 and 20). There was not a statistical difference for shoe type among the three candidates. Ratings for all three shoes, for males and females were close to 4.0 or "good."

- *Question (#24): Please give an overall rating for these shoes.*

Scale:				
Very Poor	Poor	Fair	Good	Very Good
1	2	3	4	5

TABLE 19:

Shoe Type	Direct Attachment		Welt/Cement		True Welt	
	Male	Female	Male	Female	Male	Female
Overall	96.8%	88.0%	93.3%	83.6%	94.4%	85.5%
(% of respondents who answered "fair", "good" and "very good")						

Overall (continued)

TABLE 20:

Shoe Type	Direct Attachment			Welt/Cement			True Welt		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Overall Rating [1]	4.18	3.96	4.08	3.99	3.57	3.79	4.07	3.63	3.84
(mean responses)									

1 = Statistically significant difference at a 95% Confidence Level for Gender

Discussion

The overall ratings for all three shoes were positive. However, the Direct Attachment and True Welt shoes were favored slightly over the Welt/Cement shoe in most categories. In general, male respondents rated all three shoes more positively than did their female counterparts for most factors measured. It should be noted that the only time respondents were actually fit by an issuing officer was for Phase I (Direct Attachment shoe); thereafter, participants were issued the same size for the Welt/Cement and True Welt shoes.

There were no differences in the way respondents rated the fit of the three shoe types if issued the correct size shoe. For the fit criteria, males rated the True Welt shoe as fitting more often than the Welt/Cement but not the Direct Attachment shoe. For the Direct Attachment shoe, arch fit was significantly better than the Welt/Cement shoe but was not better than the True Welt shoe. All shoes were rated positively for like or dislike of the overall fit, with mean scores between "neutral" and "like moderately." Thus, for the fit criteria, the Direct Attachment and True Welt shoes were preferred slightly over the Welt/Cement shoe.

The wear time criteria indicated the Direct Attachment shoe was worn most frequently among the three shoes. The Direct Attachment shoe was also worn during the week more often than the other three shoes, perhaps reflecting the respondents slight preference for this shoe in some categories.

The comfort criteria analyses indicated the arch support in the Direct Attachment shoe was more comfortable than the Welt/Cement shoe, but not significantly more comfortable than the True Welt shoe. The same pattern was true for ascending ladders. When respondents descended ladders, they rated the Direct Attachment shoe more comfortable than either of the other shoes. Again, the comfort of the Direct Attachment and True Welt shoes were preferred slightly in some categories to the Welt/Cement shoe. Mean responses in the comfort ratings indicated all three shoes were "ok" to "comfortable."

The Direct Attachment shoe had significantly better traction than the Welt/Cement shoe but not the True Welt shoe for the ladder and smooth steel conditions. The Direct Attachment also had significantly better traction than the True Welt but not the Welt/Cement for oil covered, carpet, pavement, and mud conditions. In wet/moist conditions, the Direct Attachment shoe had significantly better traction than both the True Welt or Welt/Cement shoes. The slight traction preferences for the Direct Attachment shoe may reflect the fact that the tread pattern on the bottom of the shoe was slightly different from the Welt/Cement and True Welt shoes.

Durability was equivalent among the three shoe types. Most reported problems reflected normal wear and tear. The ease of maintaining a military shine was also equivalent among all three shoes and rated overall as "fairly easy" to attain. The overall look of the shoes was not significantly different among all three shoe types either. All mean shoe ratings were between "fair" and "good."

In conclusion, this study was aimed at determining which of the three candidates would be suitable replacements for the current *Oxford shoe*. Given the positive ratings received by all three shoes, any of the three candidate shoes would not be a bad choice. However, the Direct Attachment and True Welt shoes were slightly favored over the Welt/Cement shoe in most *fit, wear time, comfort, performance and durability* categories.

Appendix A:

Oxford Shoe Issue Sheet

Phase: 1 2 3

Oxford Shoe

(Issue Sheet)

1. Name: ____________________ 5. Phone: (   )   -

2. DOB: ____/____/____ 6. Rate: ____________________

Day Month Year

3. SSN: _ _ _ _ (Last Four Numbers) 7. Ship: ____________________

4. Sex: (Check or Fill) ◯ 1 Male ◯ 2 Female 8. Division: ____________________

9. Race: (Check or Fill)
- ◯ 1 American Indian / Alaskan Native
- ◯ 2 Asian / Pacific Islander
- ◯ 3 Black (not of Hispanic Origin)
- ◯ 4 Hispanic
- ◯ 5 Mixed
- ◯ 6 White (not of Hispanic Origin)
- ◯ 7 Other: ____________________

10. Do your feet have any medical conditions at present? ◯ 1 Yes ◯ 2 No

If <u>YES</u> please explain: 10e. ____________________

(Shaded Area to be filled in by Issuer)

Measured Brannock Sizes

Left Foot

Right Foot

11. Length / Size: ____________________ 12. Length / Size: ____________________

13. Width: ____________________ 14. Width: ____________________

Issued Shoes

15. Size: ____________________ 16. Width: ____________________

17. Shoe Type: (Check or Fill)
- ◯ 1 Direct Attach
- ◯ 2 Welt (True)
- ◯ 3 Welt (Cement)

18. Rate the Fit†: (Check or Fill)
- ◯ 1 Good
- ◯ 2 Adequate
- ◯ 3 Poor (Best fit possible with available shoes)

† Fitters: it is important to fit the shoes as accurately as possible, since the aim of this study is to evaluate both the design and fit of the shoes.

Appendix B:

Oxford Shoe User Survey

Oxford Shoe

(User Survey)

1. Name: ______________________ 2. DOB: ____/____/____
Day Month Year

3. SSN: _ _ _ _ (Last Four Numbers) 4. Date: ____/____/____
Day Month Year

Thank you for your participation in this study. This survey is asking about the Oxford shoes which were issued to you approximately two months ago. Please answer each question as completely and honestly as possible, and provide comments where asked. If a question does not have space, comments may be written in the margins or at the end of the survey.

For questions which give several choices of answers, please **CHECK or FILL** the circle next to your response or responses.

Example: Are you currently on active duty? 45a. ✓1 Yes ○2 No

Fit of Shoe

1. OVERALL, did the shoes fit?

5. ○ 1 Yes ○ No ⇨ If NO, was the shoe... ○ 2 Too Tight ○ 3 Too Loose ⇨ Please Explain: 5e. ____________

2. Do you feel that you were issued the correct size of shoes?

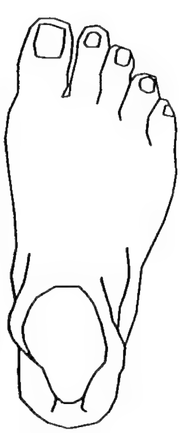
6. ○ 1 Yes ○ 2 No ⇨ If NO, please explain why ... 6e. ______________________

3. Are there any specific areas of your feet where you feel that these shoes did not fit you PROPERLY?

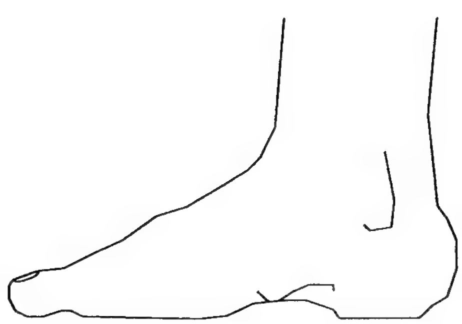
7. ○ Yes ○ No

If YES, please indicate these areas by placing an X on the diagrams below, stating whether the fit is TOO TIGHT or TOO LOOSE.

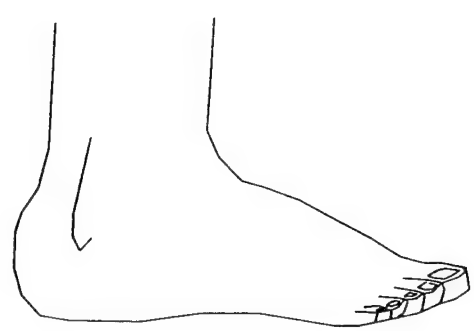
7t.



7i.



7o.



Please rate the **fit** of the shoes for the following areas, stating whether it is **acceptable** or **unacceptable**.

	Tight 1	Slightly Tight 2	Just Right 3	Slightly Loose 4	Loose 5		Is the fit... Acceptable	Unacceptable
8. Toes	○	○	○	○	○	⇨	○	○
9. Heel	○	○	○	○	○	⇨	○	○
10. Arch	○	○	○	○	○	⇨	○	○
11. Top of Foot	○	○	○	○	○	⇨	○	○
12. Ball of Foot	○	○	○	○	○	⇨	○	○
13. Overall	○	○	○	○	○	⇨	○	○

- Please rate how much you **like or dislike** the **overall fit** of the shoes.

	Dislike Very Much 1	Dislike Moderately 2	Neutral 3	Like Moderately 4	Like Very Much 5
14. Overall Fit	○	○	○	○	○

Please explain your rating: 14e. ______________________________

____

Wear Time

- Please estimate **how many weeks** during this test period you wore the dress shoes.

Never Wore	One Week	Two Weeks	Three Weeks	Four Weeks	Five Weeks	Six Weeks	Seven Weeks	Eight or More Weeks
15. ○ 0	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8+

- Please estimate, on average, **how often** or **how many times** you wore these shoes in a week.

Never	Once	Twice	Three Times	Four Times	Five Times	Six Times	Seven Times	Other
16. ○ 0	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ ________ Times/Wk

- On average, when you wore the dress shoes, for how many **hours** did you wear them at a time?

17. __________ Hours

- Please list the **three** main **duties** you performed while wearing the dress shoes, and estimate the percentage of time you spent completing each duty.

Percentage of time spent completing duty

	Duty		25%	33%	50%	66%	75%	100%	Other
18d1.	1: ____________________	p1.	○	○	○	○	○	○	______%
18d2.	2: ____________________	p2.	○	○	○	○	○	○	______%
18d3.	3: ____________________	p3.	○	○	○	○	○	○	______%

Comfort

0. Please indicate the **overall comfort** of the shoes.

19. ○ 1 Very Comfortable
○ 2 Comfortable
○ 3 OK
○ 4 Uncomfortable but Bearable
○ 5 Uncomfortable and could not wear for long

1. Please rate the shoe's arch support.

20. ○ 1 Too Low ○ 2 Just Right ○ 3 Too High

2. Please indicate the **comfort level** of the arch supports.

21. ○ 1 Very Comfortable
○ 2 Comfortable
○ 3 OK
○ 4 Uncomfortable but Bearable
○ 5 Uncomfortable and could not wear for long

3. Please indicate the **comfort level** of the shoe inserts.

22. ○ 1 Very Comfortable
○ 2 Comfortable
○ 3 OK
○ 4 Uncomfortable but Bearable
○ 5 Uncomfortable and could not wear for long

4. Did you need to use any additional inserts or cushioning with the shoes?

23. ○ 1 Yes ○ 2 No
↘ If YES, please explain what you used and why: 23e. ______________________________

____

5. Did you need to use more than one pair of socks with the shoes?

24. ○ 1 Yes ○ 2 No
↘ If YES, please explain what you used and why: 24e. ______________________________

____

6. For the following conditions please indicate how **Comfortable or Uncomfortable** the shoes were.

	Very Comfortable 1	Comfortable 2	OK 3	Uncomfortable but Bearable 4	Uncomfortable and could not Wear for long 5
25. In **Hot** Conditions	○	○	○	○	○
26. In **Cold** Conditions	○	○	○	○	○
27. While **Standing**	○	○	○	○	○
28. While **Walking**	○	○	○	○	○
29. While **Marching**	○	○	○	○	○
30. While **Running**	○	○	○	○	○
31. While **Ascending** Ladders	○	○	○	○	○
32. While **Descending** Ladders	○	○	○	○	○

17. Did the shoes cause you **any problems** while completing your **regular** activities?

33. ◯ 1 Yes ◯ 2 No

↘ If YES, please explain what activities and how the shoes hindered you: 34e. ____________

____

18. Did the shoes cause any of the following problems?

34. ◯ 1 Aching Back ◯ 4 Blisters 34o. ◯ 7 Other: ____________

◯ 2 Aching Feet ◯ 5 Callouses

◯ 3 Aching Legs ◯ 6 Foot Cramps

18b. If you experienced any problems how long did they continue?

34l. ____________ Days

18c. Did these problems require medical attention?

34m. ◯ 1 Yes ◯ 2 No

↘ If YES, please explain: 34e. ____________

____

19. How long did it take to "break-in" the shoes?

35. ____________ Days **Or** 36. ◯ 0 Did not need to be "broken-in"

◯ 1 Could not be "broken-in"

Performance of Shoes

20. Please rate the shoes' **traction** on the following surfaces:

	Poor 1	Fair 2	Good 3		Please Explain:
37. Waxed (Tile Deck)	◯	◯	◯	⇨	____________
38. Oil Covered (POL)	◯	◯	◯	⇨	____________
39. Wet/Moist	◯	◯	◯	⇨	____________
40. Non-Skid	◯	◯	◯	⇨	____________
41. Painted	◯	◯	◯	⇨	____________
42. Wooden Surface Floors	◯	◯	◯	⇨	____________
43. On Ladders	◯	◯	◯	⇨	____________
44. Smooth Steel Decks	◯	◯	◯	⇨	____________
45. Carpet	◯	◯	◯	⇨	____________
46. Pavement	◯	◯	◯	⇨	____________
47. Mud	◯	◯	◯	⇨	____________
48. Grass	◯	◯	◯	⇨	____________

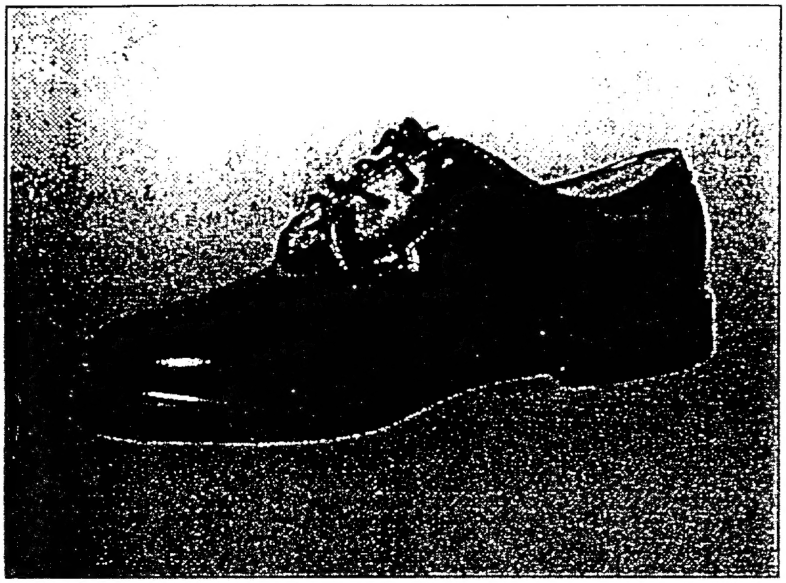
Durability

21. Did your shoes get damaged in any way? (Rips, Tears, Scratches in the Leather, Seams Separate, etc.)

49 ( ) Yes ( ) No

↘ If YES, please indicate where the shoes were damaged by placing an **X** on the pictures below, state what the damage was and how it occurred.

49s



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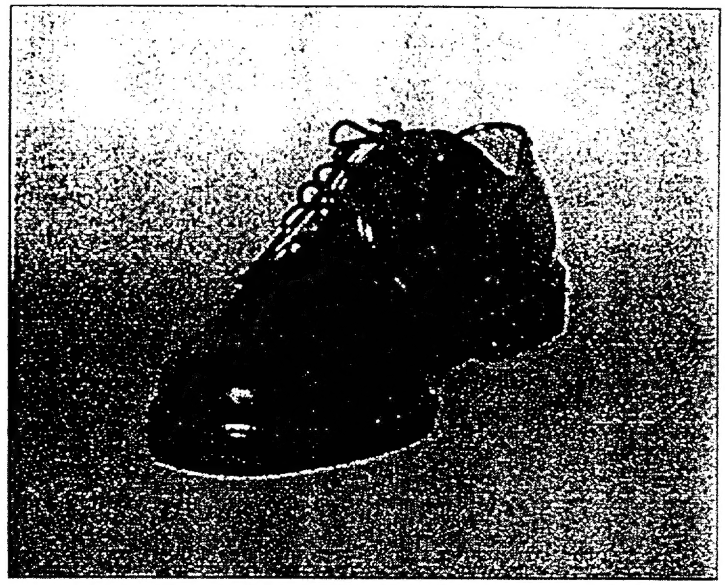

2' 'lease rate how **easy or difficult** it is to maintain a professional military shine to these shoes.

	Very Difficult 1	Fairly Difficult 2	OK 3	Fairly Easy 4	Very Easy 5
50. Ability to Maintain Shine	◯	◯	◯	◯	◯

23. Please rate the **look** of the shoes.

	Dislike Very Much 1	Dislike Moderately 2	Neither Like Nor Dislike 3	Like Moderately 4	Like Very Much 5
51. Look of Shoes	◯	◯	◯	◯	◯

24. Please give an **OVERALL** rating for these shoes.

	Very Poor 1	Poor 2	Fair 3	Good 4	Very Good 5
52 Overall Rating	◯	◯	◯	◯	◯

25. Do you have any additional comments or recommendations about the Oxford Shoe?

53. ____

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